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OF THE

PROVINCIAL MEDICAL AND SURGICAL

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THE

ADDRESS IN MEDICINE,

BEING

AN ESSAY ON THE PRINCIPAL CAUSES WHICH UNITE IN PRODUCING AND DIFFUSING DISEASE;

READ BEFORE

THE 17TH ANNUAL GENERAL MEETING

OF THE

PROVINCIAL MEDICAL AND SURGICAL ASSOCIATION,

HELD AT WORCESTER, AUGUST 1ST AND 2ND, 1849.

BY CHARLES WILLIAM BELL, M.D.,

Knight Commander of the Persian Order of the Lion and Sun; Physician to the Manchester Royal Infirmary; Consulting Physician to the Ardwick and Ancoats Dispensary; late Physician to Her Majesty's Embassy to Persia, in Medical charge of the British Detachment serving in Persia; late Physician to the Royal Household of Persia, and to the Persian Armies; formerly House Surgeon to the Middlesex Hospital.

SIR AND GENTLEMEN,—When the founders of this Association instituted the annual Address in Medicine, its objects were fixed and definite; they were to collect and analyze the various contributions of the preceding year to medical science, and to present to the members a mass of valuable information, which few of those occupied with the anxieties of practice could afford time to acquire for themselves.

Thus to select only what was really valuable from the mass of works and periodicals, relating to medicine in all its branches, that yearly issue from the press of various countries, was no ordinary task; for to distinguish new matter from old, truth from false theory, originality from plagiarism, required a rare union of industry and high literary attainments with great professional knowledge and practical judgment.

So well, however, was this difficult duty performed, season after season, by the various members by whom it was undertaken, that these Retrospects were highly appreciated by the profession in general, and thus the devotion of a separate periodical publication

to this object was suggested. Two such works now perfectly supply this desideratum; and we owe it to the talents of their editors that this part of the business of the annual meetings of the Association has now become unnecessary. An Address in Medicine is now substituted for the Retrospect, and the selection of the subject is left to the author of the paper. This choice, however, is by no means easy; for as the Retrospect embraced the whole range of medical and collateral science, and was therefore addressed to no single branch of the profession, an Essay to supply its place must not confine itself to questions of mere practice, nor to a fractional portion of the history of disease, but, like that of last year, involve the discussion of some great physiological law, if it is to be worthy the consideration of all who make the study of life their business or their pleasure.

Such reflections have rendered this undertaking more arduous than it at first appeared; and permit me to say, that anxious as the moment must ever be to one about to address the assembled learning and experience of England on subjects of which every one present is a master, this occasion is to me of even more than usual solemnity; for the place in which accident has called me before you for that purpose, is hallowed to me by the memory of the great interpreter of nature's laws, who guided my first steps in the study of medicine.

It was in this immediate neighbourhood that Sir Charles Bell terminated a career of unwearied devotion to the science of his profession, and the recollection that it had fallen to my lot to address you on ground so sacred, has continually suggested to me how little he would have considered what I have now to offer worthy of being submitted to so distinguished an audience. Thus have I been rendered doubly sensible of my own deficiencies.

The subject to which I would request your attention is—

THE CAUSES WHICH UNITE IN PRODUCING AND DIFFUSING DISEASE.

To attempt to review the whole of this extensive subject within the limits of an Essay, would have been inadmissible under other circumstances; but at the present moment I cannot help thinking it almost imperative on the medical profession, as a body, to give the matter their careful consideration.

During a long period the traditionary terrors of plague had so biassed public opinion, that though several commissions had been appointed by Government to inquire whether facts justify the general confidence in quarantine, as a preservative against the introduction of pestilence into the country, these investigations have hitherto all resulted in the renewed assertion of its efficacy, and of the absolute necessity for its maintenance.

Of late, however, the reappearance of cholera in England, notwithstanding such restrictive measures,—the great expense of the institution—the injury thereby inflicted upon commerce, and cruelty on individuals,—have concurred with a long respite from Egyptian plague, and better acquaintance with the diseases of other countries, to prepare the public mind for the reception of other views, and for the announcement contained in the Report recently issued by the Board of Health, that quarantine is not only useless but injurious.

This Report is written with great talent, and the practical recommendations it contains are in general so excellent, that it has been received with enthusiasm by the public press; yet there is scarcely a medical journal or review by which it is not condemned. This is the consequence of its practical conclusions having been based upon theories widely at variance with the received doctrines of medicine, and of facts having been so mixed up in the Report with what are assumed to be general laws of disease, that it is difficult to concur with the conclusions, without giving apparent assent to the speculations on which they are founded.

So decided a difference of opinion as thus results between the general and the medical press, respecting this Report, is calculated to injure the profession in the estimation of the public, by fostering a false notion that, as a body, medical men are opposed to all improvement, where so much is obviously required.

It therefore has become a matter of some importance to show that we are not in reality so ignorant of the means by which diseases are diffused as we are sometimes represented.

A tribunal, constituted like the Board of Health, has but one legitimate mode of arriving at its conclusions, viz.,—the careful examination of direct evidence: but with the medical profession it is different; for it rests with them to study the subject through

the medium of those great general laws and principles according to which (when ascertained) we find the designs of the Creator uniformly carried out. The Commission, however, has not been content to confine its investigations to direct evidence, and has ventured into the depths of theoretical medicine, propounding doctrines which, however novel and popular, are far from being proved, and demand our careful consideration.

This invasion of our peculiar province is a direct challenge to us to meet them upon the principle; and, lest we might incline to shun an engagement, we are further urged by an insinuation that the medical profession is, and always has been, in retard of the laity in practical knowledge of this subject. There remains to us, therefore, no choice, but tacitly to acknowledge the Board of Health as the highest authority on one of the most recondite portions of medical science, or to enter fairly into the discussion, not as mere critics of this Report, but as students of an important branch of theoretical medicine.

In commencing this investigation, it cannot be considered humiliating to confess that very great, and apparently irreconcileable, difference has long existed among medical men, regarding the exact amount of influence exerted by contagion in the propagation of disease, for evidence on this point is always most contradictory; and until lately we can scarcely be said to have been in possession of the elements on which to reason correctly on the subject.

It would be difficult to determine at what period contagion first began to be recognised as a source of disease; but previous to the introduction of small-pox and syphilis into Europe, it was certainly not considered by any writer so omnipotent a cause as it has since been esteemed by many. Even at the present day, notwithstanding the great amount of discussion the subject has undergone, it can scarcely be said that more than two points are to be held as universally acknowledged by the profession. One, that certain diseases, known as specific, are always communicated by contagion or infection, (which terms will presently be shown to mean exactly the same thing;) the other, that intermittent and irritative fevers are incapable of being so communicated.

But if the term specific include only the exanthemata, pertussis, syphilis, hydrophobia, and a few others, and these alone be held

indisputably contagious; and if only the intermittent, traumatic, and hectic fevers be acknowledged by all to be incommunicable, it is evident that the great majority of maladies will remain to be registered as doubtful; and in this doubtful class will be included all the great plagues and pestilences of history, as well as many other less widely-spread diseases.

Of these there is scarcely one that has not given rise to hot discussion of the question, whether each individually is or is not contagious; and as a class, these diseases have become the origin of two nearly equally numerous parties in the profession—the contagionists and anti-contagionists. It is impossible to deny that both parties are perfectly honest in their convictions; yet, that upon this subject the most diametrically opposite conclusions have been drawn by the greatest authorities in medicine, from an equal amount of experience, and after a lifetime spent in the investigation of disease. It is, therefore, a legitimate conclusion that both are partly right and both partially wrong who profess extreme opinions; and the probability is, that some element of the question has been equally overlooked by both, the investigation of which might tend to reconcile their differences.

It will be remembered by those present at the last annual meeting, that the question of contagion was alluded to, or I might rather say commenced, in Dr. Davies's highly philosophical Essay, by an attempt to classify all fevers, as respects their infectious or non-infectious character, according to the nature of their exciting causes.

The principle propounded was, that a poison which is formed in the living blood will find in the blood of others the elements of which it is composed, and therefore may be there reproduced, and thence infinitely propagated. But if the poison be formed extraneously to the body,—from elements which do not exist in the blood,—transmutation of the materials of the blood into this poison is impossible, and not being reproduced in the system, the disease it causes is necessarily non-contagious.

It is evident that this principle must constitute the basis of all argument on the subject, and probably has been long so considered, though it is only recently that the progress of organic chemistry has placed us in a position to reason upon it correctly. But this conclusion may be logical and its principle correct, and yet not be sufficiently definite to apply directly to every cause of fever.

If none were contagious but those which are specific, or if all contagious fevers were the effect of poisons generated only in the living blood, it would meet every contingency; but each day adds fresh evidence that this is not the case, and that certain poisons formed extraneously to the body are capable of reproducing themselves in the blood, and of communicating disease to others.

To prepare for the enquiry into the nature of such extraneous causes, it will be necessary, first, to define what is essential to those poisons which are never generated except in the living body, viz., specific virus; for by determining this, we shall be better prepared to distinguish what is essential to the cause of other contagious maladies, and what to that other class of causes whose elements do not exist in the blood, which do not produce communicable disease, and which belong to what Sydenham has designated the general epidemic constitution of the air.

If we review the mass of facts now collected, relating to the origin, course, and modes of propagation of disease, with the aid of that knowledge of the chemical actions which influence the decomposition of organic bodies, inculcated by Liebig, it will be found that all diseases that have been vulgarly called epidemic, from their prevalence at the same time and place, are products of one of three distinct and separate causes, or of two of these causes combined, or of all three operating together on the same individual.

Of these the first is *Specific Poison;* the second, *Putrefaction;* and the third, *Epidemic Influence;* and the remarks which are to follow are intended to prove that the first cause, "Specific Poison," is generated only in the *living* blood, is propagated only by contact, or infection, that it never produces any form of disease but its own, and that it is capable of inducing its own peculiar action, not on the whole essential elements of the blood, but only on a special material combined with them, which is not in general essential to the organism.

We consider the action of this class of morbific poisons to be defined in the following sentence, from Liebig's "Organic Chemistry." He says, "If the exciter" (to chemical action) "be able to impart its own state of transformation to *only one* of the component parts of a mixed liquid, its own reproduction may be the consequence of the decomposition of that one body."

The specific virus is here the exciter, and a particular material

combined with, but not necessarily essential to the blood, is the one component part of the mixed fluid to which the exciter can impart its own condition, and turn it into virus.

The second cause, or "Putrefaction," is that recognised chemical power by which organic particles in a state of active decomposition are enabled to induce the same kind of chemical action in bodies of similar chemical composition to which they are applied; but this cause differs from the first, inasmuch as it is capable of acting on the whole, or nearly the whole, mass of the blood and tissues, and is not limited in its operation to a special material *associated* with them; and, although its action is capable of being induced in the living body, and of being reproduced there, and of being thence communicated to others, it does not, like specific poisons, necessarily originate in the living blood.

The third cause is that which is properly termed "Epidemic Influence," or the *superimposed cause of disease*, which is not like the other two, a product of the decomposition of organic matter, —which finds no material in the body wherein it can produce propagable chemical action,—which cannot, therefore, be reproduced in the blood, or by any possibility become contagious, but which operates like other inorganic poisons, such as the various noxious gases, or vegetable or mineral poisons; or, it may be, like electricity, by affecting the nervous system, and thereby (mediately) disturbing the vital functions.

Respecting the origin of contagious fever, Dr. Mason Good quotes the remark of Sir Gilbert Blane, "That there is not a secretion or exhalation of the human body which may not be so vitiated as to produce diseases, communicable to others by contact or respiration, under fortuitous circumstances of concentration, &c.; so that there may be new maladies awaiting our species, which are still to develope themselves under the endless combinations of the incidents of human life, through endless ages to come."

There can be no doubt that all specific diseases must have arisen from some cause and at some time, however remote. Of these some have now become extinct, and a few others whose existence was before unknown have made their appearance since the dawn of science; still the number of diseases recognized as really specific is very small, and it is remarkable that the fortuitous "combination of incidents" to which any one of them first owed its origin does

not appear, with any certainty, to have occurred a second time since the world began. If, however, for the sake of argument, it be admitted that circumstances have so combined as to produce any one of this class *de novo*, it must be allowed that it is of very rare occurrence.

If we take small-pox as an example of all the others, history almost forces upon us the conclusion, that, of all the myriads throughout the world who have suffered from this disease, not one has been so affected but by the propagation of new germs from the original virus produced in the body of some ancient inhabitant of China, centuries before the disease was even heard of in Europe. To say, then, that this scourge was utterly unknown in the western world before it was introduced by the wild tribes from the plains of Tartary, who added this evil to the desolation spread by their arms over the most civilized portion of the earth, is to express a great and most extraordinary fact. It announces that before that era countless millions of human beings, in almost every circumstance of life, from the pampered patrician of Rome to the lowest dregs of the populace—from the prisoner, immured in a noisome cell, to the active mountaineer or free wanderer in the desert—had all alike carried to their graves, unconsciously and unscathed, a certain something in their constitutions that was capable of being converted into deadly poison by one infected breath. It asserts that their bodies contained a material, of which the existence could not even have been suspected till its presence was evinced by the transmutation effected in it by the contact of a specific reagent.

Experience has proved that the special materials on which alone the several specific poisons have the power to act, though unknown as to their exact nature, are various, and frequently finite in the system; that the portion of the system capable of being so acted upon is generally of limited quantity, and not essential to existence, and that when once converted to a new and different condition, and expelled, it is not, for the most part, reproduced by the ordinary process of nutrition; that the severity of an attack is not in proportion to the quantity of the poisonous reagent introduced into the system, but to the quantity and condition of the material contained in it, upon which the virus is capable of acting. It is also known that there will be complete immunity

from attack, (whatever the quantity of the poisons introduced into the system,) if this *materies* have been expelled by previous action, and not reproduced; and if, by a rare idiosyncracy, the body be devoid of this material.

That substances not necessary to life, and moreover capable, by simple rearrangement of their elements, of becoming absolutely destructive to vitality, should be thus combined with the essential elements of the body, is sufficiently extraordinary; but it is not less so that the destruction and extirpation of a material almost universal in the human body, should not be followed by any appreciable influence on the general health, after the dangerous fever that is produced by its formation, and which conduces to its elimination, is once over.

One of the most interesting illustrations of the agency of specific virus on its special *materies* is to be found in the discovery of Jenner,—that a particular poison taken from the lower animals, or rather human poison, modified by transmission through the constitution of the cow, is capable of acting on the matter upon which alone the small-pox virus can exert its power in such a manner as to convert and expel it from the system; or so to change its nature, that the subsequent specific agency of variolous infection becomes impossible, or greatly modified.

One of the best and most familiar illustrations of the law quoted from Liebig, by which the action of specific poisons may be explained, is the effect of adding active ferment to a saccharine solution that contains a small and definite proportion of mucilage. When fermentation is thereby induced, the gluten is acted upon, atom by atom, till the whole of it has become converted into new ferment; but when the whole of the gluten contained in the solution has been so converted, further production of the ferment ceases, from want of material to which the exciter can impart its own state of transformation. The parallel of this with exanthematous fever is exact. When the virus is introduced into the mixed fluid of the blood, all the *materies morbi* it contains is converted by it to its own condition, and the production of fresh virus only ceases after all that this exciter has power to act upon has been consumed. But, further, if a small portion of the gluten that is undergoing transformation be transferred from the first solution to another similar one, it will propagate the same action to all the

gluten it contains, and so will a small portion of the virus thrown off from the blood of one person and absorbed into that of another propagate its action to all the *materies* that is present in that body. The parallel, however, does not stop here, for if active ferment be thrown into a solution in which no mucilage exists, or from which the gluten has been previously exhausted, no new ferment will be generated; so will the introduction of virus into the blood be of non effect on those who by idiosyncrasy are fortunate enough to be without its special *materies*, or from whose system it has been eliminated by a previous attack of the disease, and not reproduced.

As an example of the same action taking place in the living body, but reversed, we may instance diabetes mellitus, for there the exciter exists in the body, and the *materies* is introduced, whereas in specific disease the *materies* exists in the body, and the exciter is introduced.

When malt, which contains diastase, is bruised and thrown into a warm solution of starch, a rearrangement of the elements of the starch is immediately induced, and it is converted into sugar. In diabetes, any starch that is conveyed into the digestive organs is immediately similarly converted, probably by some diseased secretion of the stomach or bowels analagous to diastase, and capable of communicating to it this state of transformation; the sugar thus formed becomes a source of irritation to the system when absorbed, and the kidneys are excited to increased action to expel it from the blood. But if the supply of this *materies* (fecula) be stopped, and only such aliment be taken as contains no particle of starch, the formation of this source of irritation is cut off, the sugar previously formed in the system is soon expelled by the appropriate emunctories, and the symptoms of the disease cease, while the secretion which acted as the exciter remains dormant and innocuous in the system.

The foregoing considerations will demonstrate how little there is of real distinction between contagion and infection, and that actual contact of particles, in the peculiar state of chemical activity, that is capable of communicating the like condition to particles of similar composition, is always necessary; that it is, in fact, the same process, whether the contact of the exciter with the mixed fluid of the blood be effected by matter directly introduced into the blood by the lancet, or absorbed by the pores of the skin from contact, or

introdueed by means of invisible particles, exhaled with the sufferer's breath, and absorbed through the delieate membranes of the lungs of others.

The various modes by which absorption of sueh matters may take plaee are sufficiently obvious; but those by which their elimination from the system is aeeomplished, after they have been formed in the blood, are somewhat more obscure.

The remarkable phenomena observed upon the skin in those diseases which are best known to all as contagious, (viz., the exanthemata,) together with the very obvious manner in which small-pox is communicated by inocculation, have naturally led the vulgar to regard the skin as at least the prineipal organ by which disease is propagated, or even as the actual seat of the disease, to the neglect of the less palpable means of infection, by the absorption of active particles of the exciter from the breath.

It wants, however, but little consideration to perceive that the poison of the exanthemata is not formed in the skin, but generated in the blood, and deposited in the skin. Many elementary poisons, sueh as mercury and iodine, which cannot possibly be formed in the skin, produee eruption. These are matters whieh, if imbibed in moderate quantity, are removed by the natural emunetories of the blood without disturbance; but if introdueed faster than they can be so eliminated, are thrown off by a vital effort from the more vital organs, and deposited in this part of the system, where their presenee can be tolerated without material injury, until time is afforded for their extrication by perspiration and by the other eliminating actions.

Eruption, then, commences subsequently to the formation of virus in the blood, and the deposition of the poison in the skin is solely the result of a proteetive febrile aetion excited in the blood-vessels; the virus then aets as an irritating foreign body in the skin, and requires for its extrieation more or less of the self-same reparative action than is necessary for the extrusion of a thorn.

The pus of a small-pox pustule, therefore, is not *the virus*, but only the *vehicle* of its extrication, with which the exciter is mixed up, and the poison is no more entitled to be eonsidered as originally formed in the skin than the urates (deposited by a similar protective aetion in a gouty joint) can be held to be generated in the great toe, or, than the pus, which we know to be formed in the

veins, in phlebitis, and so mingled with the circulating fluid, to be actually generated in the joints or cellular membrane in which we discover it deposited.

The excess only of the poison over that which the natural exhalations are capable of expelling is thus deposited in the skin, and it is probable that it is not till the other organs are overtasked that the skin ever becomes the temporary depository of the superfluity. Cases indeed not unfrequently occur of genuine scarlatina where the virus is removed by the emunctories of the blood, so *pari passu* with its formation in the system that no such accumulation in the skin takes place as is necessary to produce the characteristic effects of its irritation; but these are very different from those cases in which the eruption is correctly said not to come out, or has receded; such are evidences only of the want of that protective power of vitality necessary to cast the superfluity aside, not of the cessation of its formation. Pertussis is an example of the formation of a specific poison in the blood, of which the fever evinces intolerance in the system, and which we know to be at length eliminated from it; but here, although the skin is probably an active agent in its exhalation, it is either not made the depository of the poison, or at least not as an irritant,—indeed, recent pathological research seems to point to another portion of the body as the receptacle of this accumulation.

It has been remarked that the various special materials on which the different exciters of specific action operate, (although necessarily as various as the diseases produced by their conversion,) generally exist in the system in limited quantity, and are not reproduced; exceptions, however, occasionally occur even in those diseases which commonly appear only once in a lifetime, which prove that their *materies* is sometimes reproduced by nutrition; but it is evident that this reproduction is effected very slowly, as even in those exceptional cases, the virus of small-pox for instance, may be introduced some months after an attack without effect, and yet the disease be taken naturally at a later period.

But these exceptions to the general rule of the protective power of a first attack of an exanthematous fever against a second, rather aid than impede the consideration of those other specific diseases in which a first is no impediment to a subsequent infection, and in which the *materies morbi* is not finite, as in the others.

In some diseases, such as syphilis, the material acted upon appears to be constantly reproduced along with those which are more essential to organic life; and in syphilis, the poison generated is not of that violently irritating character which requires an intensely excited action of the powers of life (or fever) to throw it off upon the less important organs. The tissues are tolerant of it to such a point that its accumulation in them will destroy their organization, not so much by an effort to throw it off, as by producing an incessant irritation; yet even here we find the *vis vitæ* resisting the morbid influence in the more vital organs, and in them no evidence of disease is to be detected, even where the deepest seated bones have suffered.

This class of specific poisons has no natural means of cure, like the exanthemata, where the patient must die unless the system be immediately relieved from their irritating presence; yet experience has proved that syphilis, at least, is not beyond the means of artificial cure. The materials of its agency are not very rapidly reproduced; and it has been discovered, that by carefully restricted diet, it is possible so to reduce or cut off the supply, that for want of matter for the exciter to convert to its own poisonous condition, its action ceases, and that portion of virus which had been previously formed, will, in a few weeks, be so effectually removed from the system by the natural emunctories of the blood, as to be no longer present to renew itself when its *materies* is again supplied by better nourishment. We have also ascertained that certain medicines or chemical reagents, such as mercury and iodine, possess the power of so combining with, or altering this material, as to nullify the operation of the specific poison on it, so long as their influence is maintained; and that by keeping up this action for a period sufficient to allow the whole of the virus to be eliminated by the natural emunctories, the disease will be expelled. That it is not upon the virus previously engendered, but upon the *materies* on which the virus is capable of acting, that mercury operates, appears probable from the well known fact, that the most violent effect of mercury on the system is no more effectual in hastening the cure or preventing a relapse of syphilis, than the most gentle evidences of saturation of the system; whereas, if the exciter alone were acted upon, the larger the quantity of mercury infused into the blood, the more perfect and the more rapid would be the cure.

It is much to be regretted that the importance of this principle is not always sufficiently recognised in the treatment of the disease, and that the action of the medicine is not always sufficiently long maintained to give time for the complete elimination of the exciter; for if even a few germs be suffered to remain, they will certainly renew the morbid action as soon as the material is again supplied by nutrition in a condition amenable to its operation, and then there is danger of its becoming so modified by constitutional peculiarity as to be rendered more difficult to eradicate by means which would have been effectual in the first instance.

To pursue this subject into its more interesting details in other specific diseases, would lead too wide of the object proposed, and might appear to argue greater confidence in specific medicine than experience would justify. Still it is only upon the principle of the gradual conversion of a special material (non-essential and finite, or uneliminable and essential to life) that we can satisfactorily account for the observed phenomena of specific disease.

In so far as we have yet learned, hydrophobia must be considered as belonging to this subdivision, being a poison that, once infused into the blood, will gradually convert to its own occult condition some unknown material, normally supplied by nutrition, and which will slowly accumulate in the body till its quantity at length becomes sufficient to produce its terrible effects upon the nervous system.

Whether the means of arresting the action of this exciter on its appropriate *materies* shall ever be discovered in this dire disease, as in syphilis, is very doubtful, for it unfortunately presents no signs of its gradual accumulation till the quantity amassed suffices to prove rapidly fatal, and we cannot even guess whether its convulsions (or even those of pertussis) have any remedial tendency, such as to promote the final elimination of the poison, were life sufficiently prolonged.

Assuming, then, that the above facts are correct, we must necessarily limit the term "*specific*" to those diseases which are caused by the action of a special reagent on a special material that is combined with the living blood; and we must conclude that the *virus*, or special reagent, and the *material* of the body on which it operates, consist of precisely the same chemical elements in different states of arrangement; that simple contact of the virus will suffice

to induce its own state of transformation on the elements of this material, but being incapable of producing this effect on materials of different composition, it can never produce any form of disease but the identical one by which it had been itself produced, and rarely indeed, if ever, be produced by other means than by direct application of its specific virus; lastly, as their materials exist only in the living blood, all such poisons must have originated in the living blood.

If, then, a disease arise from any source but contagion or infection from a living being,—if its morbific poison act on the organism of the body generally, whether on the blood or tissues, as a whole, and not on a mere adjunct,—if its action be confined to an external part only,—or if it be capable of communicating a different disease, or of acting on a different part of the body, so as to produce a group of symptoms that differ essentially from those presented by its immediate source,—there will be sufficient evidence that the disease is not specific.

It will readily be perceived that there are many diseases inducible by contagion or infection, which do not fall under the above definition. Of these, the most simple example is the dissecting room finger, or the hand of a cook wounded in trussing game too far advanced in decomposition. An organic poison, whose elements are identical with those of the blood and tissues, *but which is not formed in the living blood,* enters the wound, the hand inflames, the action induced in the wound is propagated up the arm, and the excited action necessary to resist this influence (or fever) is the consequence; yet this action, thus transferred from dead to living matter, may be reproduced in others by applying matter taken from this wound to a healthy abraded surface, or the exhalations from it may give rise to erysipelas or puerperal fever.

The difference between this poison and specific virus, therefore, is, that whereas the one is formed only in the living blood, the other may arise from dead matter—*that* operates only on a small portion or adjunct of the organism,—*this* involves in its action the whole or greater part of the organic tissues. The one produces by contagion or infection only its own special disease,—this will produce different forms of disease, according to circumstances; likewise, as the one cause affects only an unessential adjunct of the organism, which is capable of being eradicated without injury to the health, immunity

from subscquent infection may result from a first attack; but in the other the great mass of the organic elements of the body are liable to be affected by the cause, and therefore one attack will exercise no protective influence on the system against future contamination.

The organic elements of the body in general being, then, considered as the *materies morbi* of a large class of diseascs, it is necessary to inquirc what the term *organic* expresses, and what are the changes which these elements are liable to undergo, and which require that vital effort to oppose them, and remove their products, which we term fcvcr.

Evcry body that grows under the influcnce of life consists of a mass of chemical compounds, produced by certain affinities modified by vitality, and vital affinity disposes to combinations of elements that are accomplished with difficulty in the laboratory, for they differ essentially from the arrangements which the same elements would assume under the influence of ordinary or *inorganic* chemical attraction ; when, therefore, thc influence of life under which they have been formed is withdrawn, the elements of organic compounds will again fall under the dominion of the inorganic affinities, their exceptional arrangement will yield to the morc normal, and organic matters be resolved into inorganic.

If for a time the vital products retain the form impressed upon them by lifc, it is owing solely to chemical inertia; for the attraction of their elements is generally so feeble aftcr death, that when any circumstance occurs to commence chemical action in them, the progrcss of their decomposition becomes rapid, powerful, and difficult to be arrested.

This reductive action in animal bodies is putrefaction, and it not only propagates itself in the body in which it commences, but the contact of a very small portion of matter in this active state of decomposition will suffice to induce the same condition in other similar organic compounds.

Even without apparent contact, a piece of fresh meat suspended in the neighbourhood of putrid flesh will take on the same action, and become tainted in a few hours; the microscope, however, informs us that the contact in this case is real, as the atmosphere surrounding a putrescent mass is observed to be charged with minute particles in a state of activc decomposition, capable of being conveyed to a great distance.

Putrefaction, or organic decomposition, therefore, is that chemical force which is most directly opposed to the formative power of vitality.

But although the powers of life are directly opposed to those inducing putrescence, it does not follow that putrefactive action can produce no effect upon the living blood. Liebig has well remarked, that "No other component part of the organism can be compared to the blood in respect of the feeble resistance which it offers to exterior influences, for it is not an organ formed, but in the act of formation: the chemical force" (or tendency to inorganic combination) "and the vital principle hold each other in such perfect equilibrium, that every disturbance, from whatever cause, effects a change in it. The blood possesses so little of permanence, that it cannot even be removed from the body without suffering immediate change, and cannot come in contact with any organ in the body without yielding to its attractions. The slightest action of a chemical reagent exercises an influence upon it; even momentary contact with air, through the medium of membranes, alters its colour and other qualities; and every chemical action, such as the active condition of the constituents of a body undergoing decomposition, fermentation, or decay, when brought into contact with the circulating fluids, disturbs the equilibrium between the chemical force and the vital principles, and the action will propagate itself through the entire mass of the blood."

These extracts will suffice to show what dangers we should hourly incur by breathing tainted air, but for the influence of the opponent power of vitality; and that our bodies, like fresh meat exposed to the exhalations of putrid flesh, would soon be reduced to a mass of gangrene by the absorption of putrid exhalations. In truth, we are apt to forget how much we are indebted to the preservative powers of life for the resistance offered to this influence, and the removal of such noxious particles from our blood, till our attention is awakened to it by observations like that of Dr. Angus Smith, who found the condensed vapour on the windows of rooms occupied by crowded assemblies, to be always charged with animal matters in a state of most active putresence, that had been exhaled from the bodies of the multitude.

It would appear, then, that putrefactive particles may continue

for a long time to be absorbed into the system, and be either changed by the antiseptic chemistry of life, or thrown off from the body in the same state in which they were received, without their having attained sufficient power to induce their own state of transmutation on the blood. There is even reason to believe that this power of resistance may be increased by habit, as in the case of night-men and the cleansers of sewers, &c.; still this immunity is seldom quite complete, and the operation of an anti-vital cause is exhibited in the earthy cachectic hue and spongy gums, and the mental depression remarkable in the inhabitants of the worst quarters of our towns.

When the body has thus been subjected to the influence of putrefaction, removal to fresh air, and improved diet, will soon restore the vital powers to vigour; but just as good air and food will aid the powers of life to overcome the anti-vital tendency to decomposition; so will anything that may occur to depress the vital powers give ascendancy to their opponent. Loss of blood, debauchery, cold, or deficient nourishment, may each produce this effect, and then, instead of being exhaled or destroyed by the vital chemistry, the decomposing agent will become active on the organism, and give rise to the actual formation of compounds in the blood that are incompatible with life, and which must either be removed, and their action arrested, or must go on increasing till life is overcome.

But the body is wonderfully endowed with sensations to warn it of danger, and to rouse up the vital energies to resistance. The presence of this irritant excites the powers that circulate the blood to increased activity, to resist and remove this cause of injury; and this reparative action, in the case in question, is the simple typhoid or low putrid fever, endemic in our towns—*a mere struggle of the vital powers against the tendency to organic decomposition.*

So long as this struggle lasts the powers of life must labour not only to form healthy organic compounds from the blood, but to throw off the putrid particles actually formed in the body. The exhalations, therefore, from a person in this state of fever are necessarily highly charged with organic particles in the most active state of putrefaction, and any one who breathes an atmosphere thus loaded, puts himself in the same relative position to the patient as a piece of fresh meat will occupy when suspended near putrid

flesh; as surely as the meat will yield in a few hours to the power of chemical decomposition so induced, will his body become the subject of putrid fever, unless protected by great resistance of the vital powers.

Of this I shall offer an illustration. A young man, living in a healthy out-district of Manchester, in which no fever at the time prevailed, was employed in the manufacture of phosphorus matches. His health was apparently unaffected by the putrid atmosphere in which he worked, until one day the manufactory took fire. After making great exertions to extinguish the flames, he returned home wet and much exhausted; he was seized with rigors, which were immediately followed by highly putrid fever; he was covered with vibices, and died in a few days, with extensive gangrene of the intestines. The powers of life had previously sufficed to expel or neutralize the putrid particles inhaled in his unhealthy occupation, till cold, wet, and exhaustion combined to depress them; but no sooner were they thus temporarily impaired, than the anti-vital influence of putrescence became paramount, and the blood, as well as the tissues of the intestines, became subject to its destructive action. So long as the struggle was maintained by life, the active putrefactive particles thus formed in his body must have been exhaled by the excreting organs infecting the atmosphere; by these means his body became a focus of disease, and the immediate neighbours first, and then those most intimate with them, became affected with fever. All the earlier cases of fever induced by this contagion were complicated with derangement or ulceration of the bowels, as if this peculiarity had been communicated along with the infection, as much as the eruption of measles or scarlatina follows contagion of these specific fevers; but it soon appeared that this was not the case, for very shortly, cases of fever distinctly traceable to the same source, had the complication transferred to the lungs, and instead of ulcerated bowels, there was pneumonia as an almost invariable concomitant; at the first, diarrhœa and dysentery had been prevalent in Manchester, but just at this period the epidemic changed to influenza, and the fevers all over the town became more or less associated with pectoral derangement.

Here, then, was a fever which there were reasonable grounds for believing had arisen from an external cause becoming communicable, but not always producing the same form of disease, for at

first it was characterised by abdominal, afterwards by pulmonary, inflammation. In the first instance, too, so far from confining its action to a mere adjunct of the organism, its exciter affected the whole mass of the blood, and all the tissues of a portion of the intestine, evinced in the petechiæ and sphacelus; therefore the contagion was not specific. The complications of ulcerated intestine and pneumonia in the subsequent cases were the effects of epidemic influence superadded to the putrid fever; but if, instead of epidemic influence, specific poison had been applied to a body in this condition, the effects produced would have been more obvious, and might have been more decidedly traceable to a superadded cause.

It does not want much argument to show that any morbid cause, whose operation on the system is only opposed by the resistance of the powers of life, will be greatly promoted in its action by any circumstance that can depress them; but when the cause of this depression is the previous establishment of an anti-vital chemical action in the system,—which is a permanent and increasing, instead of a merely temporary, opponent to the powers of life,—it will not only promote the effect of that other morbid influence, but will itself be rendered more active by the combination.

Of the combination of the specific with the putrid causes of fever we have had abundant experience within the last two years of pestilence and famine, in the almost universal diffusion of specific eruptive typhus, imported from Ireland, as it occurred in a cellar population. Day by day thousands of the inhabitants of that unhappy country sought refuge from starvation by abandoning their homes, and after having been huddled together on board ship, arrived in Liverpool or Glasgow in the last state of destitution. There, seeking a temporary asylum in the over-crowded lodging-houses, that, even at the best of times, are notorious hotbeds of putrid fever, or in damp noisome cellars and abandoned dwellings, it was almost impossible that any one previously intact could escape contagion. An atmosphere akin to that of the gaol fever of the Black Assizes was engendered; and when these unfortunates took their way into the interior, to beg or earn their bread, they left the way literally strewed with dead, and a legacy of pestilence to all who ventured to extend to them the hand of charity, until at length this contagious and specific fever became disseminated in

nearly every town and village in Great Britain, and added its special cause to those of putrid fever which had previously existed.

Few portions of medical history are more complete than that of Irish typhus. Time immemorial rooted in that country, and never extinct, it has always been ready to break out afresh on the occurrence of any favouring influence of whatever kind, be it the depression produced by famine or by epidemic causes; and then, after the first outbreak, it has seldom ceased its ravages till it has extended itself over the whole island. A tendency has been remarked in this peculiar fever to assume the form of pestilence at intervals of about ten years, or—to use the ordinary but misapplied expression—to become epidemic. The Board of Health attributes this peculiarity solely to epidemic influence; but this is certainly a fallacy, easy to be disproved, did time permit, by a review of the various well-recorded complications which it has manifested in this and the last century in Ireland: besides, the true specific nature of eruptive typhus is now established beyond all doubt, and the immunity conferred by one attack against a subsequent infection is as fully proved as that of measles, small-pox, or scarlatina. The fact, then, is incontestible, that, whether by inhalation or contact, contagion is the one and only means by which this disease is propagated; and though its diffusion may be favoured by atmospheric or other causes, it assuredly does not depend "on certain atmospheric conditions," either for its production or diffusion, as the authors of the Report on Quarantine assert.

The decennial recurrence of typhus as a pestilence is only what used to occur in small-pox, at longer intervals, and is what must naturally be the case with all highly contagious disorders which only attack once in a lifetime; it therefore admits of simpler and more intelligible explanation by this peculiarity, than by the very problematical periodical return, at such intervals, of an unknown and improbable condition of the atmosphere.

If immunity from subsequent attack be secured by having once undergone the perilous process necessary for the elimination of the *materies* of specific typhus from the system, and if nearly every one (whose circumstances subject them to communication with the infected, and to the same depressing effects of lack of food and unwholesome dwellings,) have attained this immunity, the propagation of the contagion must almost cease, and, but for the occurrence

of a few cases here and there among those who had previously escaped, it might be supposed that the disease had actually become as extinct as small-pox is said to have been rendered in Sweden by the enforcement of universal vaccination. Experience teaches us that typhus does not so readily affect children as the other exanthemata, and that it is rather a disease of middle age; but by the time that ten years of incomplete cessation have elapsed, children have grown men, many country peasants have become towns'-people, while others whom better circumstances had contributed to preserve before have now sunk into poverty, and thus fresh food for this contagion is prepared in persons of all ages. In years of plenty, vigorous and well-nourished constitutions will resist a dose of this contagion that would suffice to prostrate those whose blood has been impoverished and vital powers depressed by deficient and unwholesome food, and in such seasons of universal famine as the last two years, few who have not previously been infected can possibly escape contagion under such wretched circumstances. It must be remembered, too, that even those who had before suffered from specific typhus, still remain subject to putrid fever, and may receive its infection from those in whom the putrid and the specific fevers are combined, as well as through the influence of the endemic causes which surround them. Hence the recent universality of fatal fever in Ireland.

When famine became general in Ireland, in 1847–8, a longer period than usual had elapsed since typhus had universally prevailed in that country. In most towns in England the disease was rarely met with; and it was remarked in Dr. Davis's Essay, that not a single case of maculated typhus had been observed in Bath for years; also, that when at length it did occur, and its contagion spread, he was able to trace its introduction distinctly to an individual. But, although specific typhus had been of late years rare, the ordinary typhoid fever endemic in our towns had always, more or less, prevailed. In 1844–5, and 1846, among many hundred cases of fever visited in dispensary practice, in the out districts of Manchester, I did not meet with a single case of specific typhus—all were either the epidemic fevers of the period, or these mixed up with the putrid fever of ill-drained and crowded habitations. In the spring of 1847, the failure of the potato crop of the preceding year, and the great depression of manufactures, which

threw thousands of work-people out of employment, combined to render land-scurvy deplorably prevalent; and the *famine fever*, or lowest form of petechial typhoid, became very frequent; but except in the two quarters of the town, inhabited almost exclusively by Irish, there was absolutely no eruptive typhus in Manchester; and even there it was as yet infrequent. This, however, did not long continue to be the case. Every wretched and over-crowded lodging in the Irish quarter was soon filled with infected families from Ireland, and became a focus of disease, and then the two causes of fever, in combined operation on the same individual, were manifested in the great majority of cases, for the specific eruption appeared mixed up with the petechiæ of putrid fever.

After this typhus rapidly spread into other districts. The multitudes attacked in the end of 1847 and beginning of 1848 were countless, for of the whole native population of Manchester scarcely one had acquired immunity from contagion by previous attack. It was not till the autumn of 1848, when most of those exposed and liable to the disease had passed through the infection, that specific typhus rapidly decreased; and since the commencement of the present year, (1849,) the number of patients admitted into the Manchester fever wards has gradually fallen to its yearly average. Of this number, only about a third are now (July) cases of true specific typhus, the others being of the ordinary typhoid of the town, modified by epidemic influence, or of that low congestive form of fever, afterwards to be described, which belongs to the reigning epidemic constitution. Of these latter, however, almost all have previously suffered within the last two years from specific typhus; if not, they are in danger of contracting it in hospital, as happened not unfrequently when it first began to prevail, and the attack was often considered as a relapse of the previous typhoid. Suffice it, then, to say that typhus spread till all who were exposed to its contagion, and who had not been previously affected, had taken it, and then it very rapidly decreased.

But the Board of Health has bound itself down to the assertion (page 5) that "Typhus, scarlatina, influenza, plague, yellow fever, and cholera, are all dependant on certain atmospheric conditions, and all obey similar laws of diffusion;" in other words, that all fevers, whether of specific or other origin, are propagated solely by epidemic influence. At page 6, this view is intended to be still

more explicitly expressed, by stating, "That without the presence of an epidemic atmosphere, no contagion can cause a disease to spread epidemically."

Not to dwell upon the only sense in which we can concur in this opinion, viz., that unless a disease be epidemic, it is not epidemic, let us inquire how far typhus, (and, of course, all other diseases of specific origin,) are influenced in their production and diffusion by an epidemic atmosphere. The experience of history, and of almost every medical man in England, has proved that without specific contagion, neither filth, crowding, nor epidemic influence, nor all these three combined, will suffice to produce either typhus, scarlatina, measles, or any other specific disease; yet we cannot doubt that each of these causes may act as a depresser of the powers of life, and so promote the action of specific virus when applied. Perfectly disposed to admit that certain atmospheric conditions may, and often do, depress the vital powers of resistance, so as greatly to promote the action of other morbid causes, our experience goes to prove, that deficient nourishment and unwholesome dwellings have been the main, if not the only, causes that have contributed to promote the diffusion of typhus and scarlatina in England during the last two years of pestilence; and we do not find that any satisfactory reasons have been shown by the Board of Health for believing that any particular state of the atmosphere must necessarily concur with so competent a cause for their diffusion, as the introduction of active specific poison among a dense population universally liable to its action, which moreover was, for the most part, predisposed to its reception by poverty and insufficient food. It is only in the vulgar sense that typhus, scarlatina, small-pox, measles, &c., can be said to become epidemic; they are specifically contagious diseases, not epidemics; and so far from obeying the same laws of diffusion with influenza, plague, or cholera, as the Board says they do, they obey laws of diffusion peculiar only to diseases which have no origin but contagion, and only occur once in a life-time, spreading so long as any who are susceptible to their contagion continue to be exposed to it, but no longer, whatever the nature of the epidemic atmosphere. Still specific fevers are not wholly uninfluenced by epidemic causes. The very derangement of health, caused by contagion, renders the whole

system more amenable to epidemic influence, and wherever such influence exists, it will more or less modify the course of any individual case of fever.

We have endeavoured to define epidemic influence according to its literal meaning, as a superimposed cause of disease, one which produces no propagable action on the body, but which, acting like some inorganic or vegetable poisons received into the blood, or by means of some unknown external agency, such as electricity, affects a portion of the nervous system, and thereby produces disturbance of some particular function or organ. It remains, then, to enquire how far such influence has been manifested upon fever in the course of the last two years in which the specific pestilence of typhus has been so widely spread.

In the early part of 1848, when specific (improperly termed epidemic) typhus was at its height in Manchester, the town was even more than usually free from all signs of epidemic influence, and fever displayed no remarkable tendency to complication with disorder of any particular organ. A large proportion of cases from the worst neighbourhoods and cellars, it is true, exhibited the influence of the endemic or putrefactive causes in combination with the specific contagion, as shown in the admixture of petechiæ with the true papular eruption of typhus, and in the frequent occurrence of extensive gangrene in the neck of children affected with scarlatina, for we know that petechiæ and gangrene, though they belong to the worst forms of typhoid or putrid fever, are not in any way essential to either typhus or scarlatina. Still there was remarkably little tendency to any other kind of complication or diseased action of any organ of the chest or abdomen, or of the brain, such as we always perceive where epidemic influence is active, and which must have been the case had the Board been correct in attributing the diffusion of these specific fevers to "some peculiar condition of the atmosphere."

In June, however, a really epidemic influence was manifested. Dysentery became prevalent in the town, and every case of fever was then complicated with derangement or ulceration of the bowels. This ceased in a few weeks; but in August, the remarkable tendency to venous congestion, which always accompanies the epidemic influence that belongs to cholera, began to be felt, as the disease approached our shores. Throughout September the cases

admitted were chiefly of a low congestive character, with mottled chilly skin and black tongue, with small contracted pulse, and tendency to morning remission, exhibiting great disposition to relapse. The cases of specific typhus showed less of these characters, probably in consequence of the excitement produced in the arterial system by the presence of the specific irritant, but they also were generally complicated with severe congestion of the brain and portal system. At the same time every case of scarlatina indicated the same congested condition of the kidney by the increased frequency with which the attack was followed by albuminuria and dropsy, and by the greater severity of these symptoms.

In December this feature changed, influenza became prevalent, and then almost every case of fever, of whatever kind, was complicated with bronchitis.

In May and June this again gave place to the same congestive fever that had been observed in September, and at both of these periods a few cases of cholera occurred.

Such, and such like, are the only true effects of an epidemic atmosphere or influence on specific fever, and such effects are always even more evident on fever which has its origin in putresence without specific intermixture.

If, then, at any time we observe specific fever to be accompanied with the petechiæ and tendency to gangrene that belong essentially to typhoid fever, we may consider both causes in operation on the system; and when, in addition to the characters which we know belong only to the specific disease in its pure state, or to the typhoid form of fever, we observe a general tendency to affection of a particular organ, or of one part of the system more than another, we are entitled to consider this complication the result of epidemic influence superadded on the other causes of disease.

This will become the more evident if we also observe that the organ chiefly affected in fever is that which, for the time being, is most liable to derangement in those who are merely attacked with cold, &c., without other cause of fever. Every practitioner knows that when slight causes of depression, such as cold, are succeeded by reaction, and inflammation of the throat, the lungs, the pleuræ, the bowels, or of any particular organ in one or two persons at the same time, he will probably soon meet with other

cases of the same character; and he expects that when he goes into the fever wards he will find more or less complication from disorder of the same organ in almost every case. These are the results of epidemic influence, and such complication affords the most legitimate means of studying the effects of these causes. It was by the attention which he bestowed on such complications that Sydenham did so much to improve his profession; and there certainly does not exist a subject of greater interest in the whole wide range of medicine than to observe, and carefully note, the extraordinary multiplicity of functions and organs that are thus, month by month, and year by year, affected by the epidemic influence. Now one set of glands in the intestines will be affected, now another. Now the lymphatic system, as in plague. Now the skin, as in sweating sickness, erysipelas, &c. Now the influence will attack the joints and muscles, with rheumatic inflammation, or the serous membranes, by producing pleuritis, peritonitis, meningitis, endo and peri-carditis. Now it will disturb chiefly the arterial system, and cause excitement and active inflammation; or the venous, producing disorder of its functions in agues, cholera, remittents, and passive congestion of various organs, such as the lungs, the spleen, the brain, the liver, or the kidney.

Suppressio urinæ, diuresis, the formation of oxalates, vomitus, diarrhœa, constipatio, icterus, spasms, convulsions, neuralgiæ, paralyses, &c., &c., are all on record as the effects of disturbance of the various vital functions and organs produced by epidemic influence; and even those still more unintelligible functional disorders of the brain that result in strange psychical derangements, evinced in the dancing mania and tarantulism.

The subject is too vast to be more than hinted at; but infinite as may be the variety of causes to which the great epidemics of history have been attributed, such as tides, winds, mists, earthquakes, volcanoes, comets, electricity, and every mysterious cause included under the term "divine wrath," it will be found that the effects of epidemic influence on the human constitution are even yet more varied. It is possible that all these causes may ultimately be resolved into three, viz.,—poisons floating in the atmosphere, poisonous ingesta, and the disturbed balance of the electricity of our bodies in reference to that of the earth or air; but such speculations will avail us little. In the meantime

we have rather to do with effects than causes, until, perhaps, advancing science may one day permit of general laws being deduced from the accumulation of well observed facts. Practically we are as yet only entitled to consider epidemic influence as a cause of disease that will manifest itself for a time in morbid derangement of some function or class of functions, and so render some organ or class of organs more than usually prone to disease; that will extend itself over large districts in the course of a few hours, under circumstances for which no probable theory of contagion will account, and as one that is in no case capable of directly inducing propagable morbific action in the system, or of converting any part of the elements of the body to its own condition, so as to render that body a focus of disease; for this is the only mode in which it appears possible for any disease to become contagious.

But although not capable of regenerating itself in the body, and so becoming communicable, the *epidemic influence* is capable of giving activity to other morbific causes previously dormant in the system, whether specific or putrefactive, by the depression which it produces on the powers of life. It will thus aid in the production of propagable disease, which it cannot itself originate, and will moreover give to such diseases a pseudo-specific character, by superimposing upon them the peculiar derangement of function, which it is its province to produce.

It appears to be only thus that the incessant variations of our towns' fevers can be accounted for, from month to month or year to year, or, we may add, from era to era.

Each man in his generation is witness to many such changes in the character of disease; but it is only from history that we learn that such are but the minor phazes of great epochs of disease, of which the grander features imprint their general character on the less.

At the commencement of this century highly inflammatory affections were predominant; but since 1828 the lancet has been little used, and every kind of tonic treatment has come into vogue, yet we see that even in the most ancient times such changes took place in the usual plans of treatment. Galen blames Hippocrates for neglecting to mention the use of venesection in a disease where he did not venture to doubt that it had been employed, because he

himself had found it necessary. The innumerable commentaries on these works bear testimony to this ever-varying character of disease; one learned writer, judging from his own experience, accuses the great father of physic of error, while another, in a diffcrent generation, and for similar reasons, condemns the commentator, and pins his faith to the original. The change of the means of ministering to disease, so as to adapt the remedies to the exigences of the period, is too often attributed to fashion only, or to fanciful theory, when it really is due to each man's experience of the necessity of altering his line of defence to meet a changed mode of attack by the disease. In general, change of *fashion* in the *treatment* of disease is evidence complete of essential change in its *character*, and is not the effect of doctrine, though new doctrines are often concurrently propounded in consequence of the effects of a temporary cause being mistaken for the *cause* itself. Thus Broussois, finding every fever he saw complicated with intestinal ulceration, taught the continental physicians that this ulceration was the invariable cause of all fever; but Broussois' authority has already passed away with the gradual change that has occurred in the type of fever; so every well-established change in medical treatment and most fashionable doctrines will mark an epoch of disease. Thus, to postcrity, the general belief in homœopathy and infinitesimal doses of the present day, will serve as evidence of the long existence in this century of a peculiarly inactive character of disease; for we know that both the doctrine and the practice of Hannemann must cease to be fashionable so soon as a more inflammatory character of disease shall reappear.

Extended examination of the subject will, I think, leave no doubt that any cause of fever, but more especially the putrefactive causes, will render the system more amenable to any epidemic influence that prevails. Thus Dr. Christison's cases, cited by Dr. Davies in his Essay, though arising only from local exhalations from putrid manure, assumed the most aggravated form of that type of fever which then prevailed throughout the country, known as the Edinburgh epidemic of 1843. Had plague then prevailed, these would have been cases of plague, with all its characteristic symptoms, just as putrid cabbages gave rise to the first cases of plague in Oxford. If cholera had been epidemic, these persons would have suffered from cholera; but as it was, the disease was a congestive remittent.

If, then, epidemic influence manifests more or less of its effects upon the system in all fevers, may we not hold it as a corollary that when an infectious fever, complicated by such influence, communicates itself by contagion to one who is not within the influence of that epidemic cause, it will be conveyed to him without these effects?—in other words, that the contagious fever will then be propagated in its simple form, without one of those symptoms that had been superadded upon it in the previous case by that cause. This is the point upon which the Board of Health ought to have concentrated the evidence, in order to prove quarantine misapplied to epidemic disease.

If, instead of considering the diffusion of all diseases to depend upon epidemic influence alone, and denying to contagion any effect whatever, they had admitted it as a settled point that small-pox, and all other diseases of specific origin, may be excluded from a country by an efficient system of quarantine, they would only have acknowledged what is fully proved by every species of evidence, direct and indirect, and equally consistent with experience and theory, and then there would only have remained to the commissioners to consider the not very difficult question of the expediency of maintaining an establishment to exclude what was already in the country, at least in so far as this particular class of diseases was concerned. But with respect to plague, cholera, influenza, and yellow fever, abundant evidence exists in our own and the French reports, and elsewhere, to show that these are not specific but epidemic diseases, that their peculiar symptoms are produced only by epidemic causes, and that although, where their epidemic cause exists, they may sometimes appear to spread by specific contagion when they are mixed up with contagious putrid fever, it is the typhoid fever that is so communicated, not the epidemic symptoms. That if a fever so combined with plague, infect any one who is beyond the reach of the epidemic cause, the fever is communicated without the plague symptoms, for the cause which alone is capable of producing these symptoms is absent. There is, also, evidence to show, that wherever this epidemic cause exists, its peculiar symptoms will immediately be superadded on the endemic fever of the country, quite independently of all contagion; and, therefore, though sanitory measures, directed to remove the causes of *endemic* fever, will

avail much to diminish the fatality and curb the extension of such pestilences, both quarantine and sanitory measures are utterly powerless to prevent their introduction into a country.

All this might have been proved by evidence, without going beyond a simple statement of facts. It is substantiable that a ship sailing from Alexandria with a crew infected with plague, only carries the contagious fever *as plague* to the limits of the epidemic influence; and that even if the contagion does propagate itself in a foul, ill-ventilated ship, beyond the reach of that influence, it is only as putrid fever that it does so, and the only disease it can communicate to a country to which that epidemic influence has not extended, is the identical form of typhoid that was previously endemic in that country, without one single attribute of Egyptian plague. For example, while I was resident in the capital of Persia, a body of cavalry came under my care, after a rapid march of two hundred miles from the district of Khŭmsa, where plague at the time prevailed, and where every one attacked with fever was affected with plague buboes. These men brought with them an aggravated form of typhoid fever; but after their arrival at Tehran, though most of them were affected with petechial fever, and two died, not one of them had buboes. In Tabreez, too, which I entered with Sir Henry Ellis's embassy, in 1835, only four or five days after plague had suddenly ceased in the town, I found cases of typhoid running their regular course without buboes, although said to have taken the contagion from plague patients who had had buboes. If, however, a ship leave Alexandria with plague on board, and cases manifesting plague symptoms are actually in it at the time of its arrival in a port, it is evident that she has never quitted the range of the epidemic influence, and that this influence has either travelled *pari passu* with the ship, or has preceded it; and, in all probability, this influence had already been manifested by superimposition of the epidemic symptoms on the typhoid fever of the worst districts of that port or neighbouring town before the ship's arrival. Such would appear to have been the case in the often quoted instance of the commencement of cholera in the Isle of France, a few days before the *Topaze* frigate arrived with cholera on board from Ceylon. But when it happens, as in the case of the *Eclair*, at Boa Vista, that the epidemic influence

does not reach a port till just after the arrival of an infected and very foul ship, and almost immediately after communication with the ship a pestilence breaks out, the connection between cause and effect appears so decided, that those who attempt to argue that *post hoc* is not necessarily *propter hoc,* are scarcely listened to with patience by the generality of mankind.

With regard to Egyptian plague, it is, indeed, rather remarkable to those well acquainted with its habitats, that although it has always been the principal object of quarantine, it presents infinitely more evidence against, than in favour of, the supposition that it can ever be propagated beyond its own limits by contagion, or become contagious in its own essence. Whatever the cause of other epidemic diseases, it is pretty evident that that of plague depends on the admixture of the winds from tropical Africa with the colder breezes of the north, as it always makes its first appearance where these winds meet and form clouds.

In Egypt, plague never precedes the southern breezes in spring, and it ceases there after that wind has become dominant and unmixed, in June. It does not then recur till the north wind again approaches the Egyptian coast, in November; and as that wind in its turn acquires the ascendancy in the winter season, plague again ceases till the following spring. Each spring and summer, plague accompanies the extension of the tropical wind towards the north, and each autumn and winter, it recedes towards the south-east, as in their turn the wintry blasts prevail and drive the point of admixture back towards the south, till it reaches Upper Egypt, where earth and air are so dry that no moisture is precipitated where they meet, no clouds are formed, and no plague is induced. Its ordinary course of late years has been as follows:—It first appears in Egypt in March; in Cyprus in April; in Smyrna in May; in Constantinople in June; at the mouths of the Danube and Odessa in July and August. Towards the Equinox, the wind becoming more westerly, plague attacks the east coasts of the Black Sea, Samsoon, and Trebizonde, and the high grounds of Armenia, from Erzeroom to Ararat, where the south winds mix with the breezes from the Caspian. As winter begins it falls back upon Damascus and Aleppo, reappears for a time in Egypt, and settles upon Mecca, and then in the next year, in March, it begins its course anew. This course doubtless

often varies, sometimes spreading far into Asia, sometimes overwhelming even the west of Europe; but in these wanderings the principle appears to be maintained, as it is said that in the years that it extends farthest into Europe, Asia is free, and *vice versa*.

To any one who has experienced the depressing effects of the plague atmosphere, it is easy to understand how its advent will act upon a system prepared for disease by the filth of an eastern city. Every one attacked by, or even subject to, the cause of putrid fever, becomes in a few hours a mass of putrefaction where the plague influence exists, and, covered with vibices and gangrene the patient presents one of the most appalling spectacles that can be imagined. The putrid exhalations that then emanate from the bodies of the sick, rapidly bring others under their influence and that of the epidemic, and then, indeed, is plague, or at least the putrid fever with which it acts in concert, fearfully contagious.

Thus as it proceeds in its annual course, so soon as the epidemic influence is felt, the endemic typhoid of every town it reaches becomes contagious plague. Nor are those exempt who have no putrid nor specific cause of disease in their systems. If depressed by previous illness, cold, or famine, they are affected with great mental depression and with colliquative sweats, and buboes appear in different parts of their bodies; but there are no petechiæ or other putrid symptoms, and these persons may mingle freely with others, without the slightest chance of conveying to them the disease. Evidence to this effect is very abundant. Such was my own case, and my servant's. In March, 1840, we sailed down the Nile on the verge of the first southerly wind, all the way from Thebes, and having thus been more than usually exposed to the concentrated cause of epidemic plague, slight exposure to wet in the Mahmoodean Canal, sufficed to bring us under its influence, and we were attacked in Alexandria with buboes and exhausting sweats; yet we lived with thirty others, on board ship and in quarantine, for upwards of three weeks without communicating the infection to any one.

It is thus only that an observation I have frequently heard from the best informed of the medical men whom I met in Egypt can be explained. They assert that plague caught by contagion is always contagious; but sporadic plague, not received by infection, is not infectious, and this I would interpret to mean,

that when combined with putrid fever it is catching, but unless combined with contagious disease is incommunicable.

The three causes of disease usually called epidemic have now been sufficiently dwelt upon to show that the *specific* is always contagious; that the *endemic*, or putrid fever, may be contagious, but may also arise without contagion; and that the *epidemic* is never contagious in itself, although it may appear to be so when mixed up with the other two.

In reference, then, to the opinions advocated in the Government Report on quarantine, though we may agree with them that plague, cholera, influenza, and other epidemic diseases cannot possibly be communicated by contagion or fomites, we cannot concur in the belief that—"Without the presence of an epidemic atmosphere, no contagion, whether imported or native, can cause a disease to spread" as pestilence; for every evidence goes to prove that specific disease diffuses itself quite independently of such influence. We object, too, to the statement that—"The notion of the propagation of plague by means of goods appears, from one uniform mass of evidence, to be as entirely unfounded as the opinion which formerly prevailed in this country, that typhus could be propagated in the same mode;" because if this were true, and plague were as communicable as typhus by means of goods, furniture, clothes, &c., we must consider it to be like typhus—a specifically contagious disease—and assert the necessity for maintaining quarantine to oppose its introduction, which is exactly the opposite to what the Board wishes to inculcate in this sentence. So far from this being the case, however, we believe quarantine quite useless against plague, though had it been possible to maintain an efficient system of quarantine against the introduction of specific typhus from Ireland we cannot doubt that very many thousand lives would have been thereby saved in Britain during the last two years.

So far, then, from acknowledging the Board of Health to be in advance of the medical profession in their knowledge of the causes by which disease is produced and propagated, we cannot but consider the commissioners in retard of the present state of information on the subject when they declare that—"Typhus, scarlatina, influenza, plague, yellow fever, and cholera, all obey similar laws of diffusion." It is, however, only justice to the Health of Towns,

and to the Board of Health, Commissioners, to acknowledge that we are indebted to them for an immense amount of most valuable practical and statistical information, and that legislation founded upon the recommendations contained in their Report on quarantine is calculated to do away with enormous abuses, cruelties, and injury to commerce, and likely to be attended only by inestimable advantages to the country. Against their practical conclusions there is nothing to be urged, but to the principles which they have propounded, as the very basis of their Report, we must object *in toto*. They have maintained epidemic influence to be the only cause of the diffusion of fever, &c., whereas we have endeavoured to demonstrate that this depends on three distinct and different causes.

We believe that all SPECIFIC diseases are propagated only by contagion, and that quarantine and isolation of the sick is the only effectual bar to the introduction and diffusion of such diseases; but as nearly every known form of specific disease propagable in this climate already exists in Great Britain, it would, at present, be absurd to maintain quarantine for this purpose, though removal of the sick ought to be more insisted upon.

We believe that all diseases properly termed EPIDEMIC are in themselves non-contagious; that their cause does not emanate from the bodies of the sick, and is not capable of attaching itself to clothes, goods, ships, or places, but that it is a pervading external influence that extends itself uncontrollably over the earth, generally or partially,—is governed by unknown laws, and affects the health through various media; that, therefore, quarantine and isolation are wholly inoperative to prevent the introduction or diffusion of diseases of this class.

We believe ENDEMIC fevers to arise chiefly from local causes, all of which are more or less preventible, and that they are capable of becoming intensely contagious—that their most fruitful cause is respiration of air loaded with putrid exhalations from mixed masses of animal and vegetable substances in a state of decomposition—their most contagious source, putrid exhalations from the bodies of beings crowded together in a confined atmosphere, such as our living gaols once enclosed, and those from persons actually suffering from putrid disease—and their most poisonous source, putrescent viands, bad meat, and sausages made from the flesh of over-driven animals, &c. &c.

But as the causes of endemic fever include every circumstance by which the tendency to chemical decomposition is promoted or induced in the living body, such as unhealthy occupations and habitations, bad air, bad food, filth, want of drainage, water, or ventilation, and as these are causes that exist almost everywhere, it is vain to think that diseases which directly arise from them can be excluded by quarantine or isolation, or that their diffusion can be prevented by any practicable means but those which are now actively in progress for the improvement of our towns.

Such, then, separately considered, appear to be the three principal causes of the more widely spread diseases that affect communities, and such their characteristics as regards their communicability from man to man; but we have endeavoured to show, that in densely inhabited neighbourhoods these seldom operate upon the system singly, and that all three frequently unite in the production of disease, and by their combination that each promotes the diffusion of the others; also, that to this admixture of causes is owing the extraordinary variety in the types of fever with which we have to contend. In the example of typhus, we have seen how specific disease may be modified by endemic and epidemic agency, and in that of plague, how a non-infectious epidemic disease may appear to acquire the virulently contagious properties of specific fever, and become the putrid pestilence that it once was in London. In the fevers of our towns we have seen how maladies purely endemic may acquire peculiarity of character from an epidemic source, and how their cause may promote the extension of specific as well as epidemic fever. The same kind of synthesis may be observed in many other forms of disease which have given rise to much controversy; thus the pestilential fever of the *Eclaire* appears to have proceeded from the exhalations from the foul mud that covered the bottom of the ship, combined with African remittent, and the contagious form of yellow fever in the West Indies to be the result of local impurities, combined with the tropical remittent of that climate. Of such combinations, the epidemic of the present season presents one of the most difficult and complicated examples. Both dysentery and cholera are at present epidemic in various parts of the country, and dysentery is a most powerful predisponent to the operation of the cause of cholera, but more especially so when it combines with the putrefactive causes to

prostrate the vital powers. We shall have occasion to show in the sequel that a most contagious form of dysentery may arise from the concentrated exhalations of putrid exuviæ, and where the epidemic cause also exists the combination of the two becomes virulent. This compound disease at present prevails among our cellar population, and appears to be allied to that which broke out among the children at Tooting, epidemic cholera being superadded to contagious dysentery. Such cases very rapidly fall into a state of almost hopeless collapse; and although this very active disease is not very readily conveyed to those who have not been subjected to the same putrid atmosphere, and its extension is easily checked by change of air, &c., it is impossible to doubt its communicability by contagion, or that the conveyance of the putrid poison of dysentery has in many cases induced intestinal derangement that has terminated in cholera.*

* There is a wide distinction between the secondary cholera above alluded to and the pure unmixed disease; for dysenteric cholera commences while the tongue and extremities are warm, with purging and vomiting of thin mucous fluid that is evidently a *secretion*, such as that produced by jalap or croton, and urine is passed with each evacuation, whereas in primary cholera the tongue is cold, the nails are blue, and secretion of urine has ceased previously to the first purging, and the stools are serous exudations.

Primary cholera begins in the peripheral circulation by loss of those vital properties of the capillary vessels by which the blood is preserved fluid and unadherent to their tubes, and by which those reactions between the blood and tissues are wrought, of which animal heat is one effect. The veins of the extremities contract, forcing their blood inwards upon the heart, and then its transmission through the lungs being impeded by a similar condition of the pulmonary capillaries, and retained by the valves of the external veins, it regurgitates upon the intestines and filters its fluid through their mucous membranes, so that great mechanical distension and congestion of the cavæ must here precede the purging. Our efforts must therefore be directed to restore and promote vital action in the paralysed capillaries, and to relieve congestion.

In secondary cholera, on the other hand, this condition does not precede the purging, but follows as a consequence of vital resistance to the epidemic influence of cholera having been subdued by the previous active purging; but cholera is not a necessary consequence of such attacks of dysentery, for in several districts in and around Manchester at this moment, very severe dysentery prevails, without being succeeded by collapse, (or very rarely,) while in another district dysenteric symptoms are liable to be immediately followed by that condition, unless prevented by most energetic treatment, of which the object is not to fortify but to subdue vital irritability in the intestinal vessels by emetics, calomel, and opium, lead, freezing mixtures, &c. When in such cases collapse follows, we see it commencing in the extremities, but instead of congestion following the rejection of their blood into the

We are convinced that the more we extend our observations of the influence of the putrefactive causes in rendering the system susceptible to the other causes of disease, the more we shall be satisfied that legislative enactments to enforce the removal of them are truly entitled to be styled laws "for the prevention of diseases;" while, therefore, we have been constrained by a due regard to correct medical theory, to resist the doctrines upon which the Board of Health has unfortunately based its arguments against quarantine, we can with pleasure concur with their excellent practical conclusions, that every improvement in drainage, ventilation, cleanliness, temperance, and the moral as well as social condition of the people, is a step towards the prevention of disease, and we cannot doubt that if the present war against filth proceed, as we have reason to hope that it will, now that its evils have been so ably exposed, England will never more have occasion to dread a recurrence of those horrors of putrid pestilence that were witnessed in the middle ages, when sweating sickness, black death, and plague desolated the land, or such melancholy destruction of the population as filth and famine, combined with specific and epidemic disease, have lately been working in Ireland.

We cannot certainly entertain the hope that all the causes of endemic disease can be rooted out and fever eradicated, so long as organic substances are liable to decomposition, and poverty is an evil, but this is no reason why we should cease from exertion till all known and acknowledged sources of putridity and pestilence, as cess-pools and burial grounds, are removed from our doors. But while we are anxious to give to the authors of these Reports the full meed of credit due to their exertions, we must not be restrained from pointing out the evil that must result if the theoretical doctrines they have propounded be generally received and acted

cavæ, and causing the peculiar struggling action of the heart observed in the primary disease, its action is feeble and subdued, because the vessels previously so excited appear at once to abandon all resistance to their distension, and the blood is no sooner driven from the extremities than its fluid is decanted off into the bowels, passive exudation of serous fluid almost instantaneously succeeding to active secretion of mucous dejections.

In the primary disease, so soon as congestion is relieved and capillary circulation is restored, the purging ceases ; but in the secondary disease, if the patient recover from the collapse, purging still continues, because active dysenteric secretion returns and runs its course.

upon. To teach "that no contagion can cause a disease to spread without the presence of an epidemic atmosphere," is, in other words, to declare that specific fevers, such as scarlatina, typhus, small-pox, measles, &c., are not contagious, and that the separation of the sick from the healthy is of no avail in preventing their diffusion. Thus, instead of encouraging the adoption of the only means by which the poor have it in their power to preserve their families and neighbourhood from infection, the direct tendency of the Report on Quarantine is to dissuade them from sending those labouring under such diseases to the fever hospital. The consequence of this mistaken theory, therefore, is, that at the very moment that they conceive they are adopting means which will result in the total eradication of every species of fever from the country by removal of the *predisposing* causes, the commissioners are advising, with the whole weight of their authority, neglect of the *immediate* cause of specific fever—direct contagion,—and are thereby ensuring the perpetuation of this particular class of diseases.

Having now considered the principal causes of those diseases which are liable to spread generally among communities, both separately and in their combinations, I ought, perhaps, to conclude; but as it will be obvious that several very important maladies, all of which are highly contagious, such as hospital gangrene, phagedena, phlebitis, traumatic erysipelas, puerperal fever, gonorrhœa, ophthalmia, &c., have not been included, I am tempted to trespass a little longer on your patience, in order to embrace a part of the subject, without which, even as a sketch, the object proposed would remain incomplete. I shall not, however, abuse your indulgence by attempting more than to indicate my own impression, that the principles already partially discussed, of the operation of specific and general exciters on organic masses composed of various materials, may be applied to these diseases also, so as to promise both interest and instruction from the investigation.

The diseases just enumerated have been very variously classified by nosologists; but viewed in reference to their causes, it would appear that they may all be arranged under one general head, as effects of chemical decomposition acting on parts external to the blood, that is, upon the tissues and secretions formed from

the blood, rather than on the mass of the blood itself, or on materials contained in it. Adopting Liebig's principle, that matter in a state of active transformation from an organic to an inorganic condition, can operate as an exciter to chemical action in substances of identical chemical composition, and on them alone, even though they be mixed up with a variety of other different materials. We applied this law to the explanation of specific constitutional disease by considering the action of special exciters on the mixed materials of the blood. We also alluded to those more general exciters to decomposition, which are integral portions of a very compound mass, and capable of reducing the whole of the materials of that mass to their own condition of general putrefaction; but these we also considered chiefly in reference to their operation on the blood, and as the ordinary sources of putrid or endemic fever. We have now, however, to observe the action of similar exciters, not on the blood, but on the tissues and secretions, that have been formed from it; and in most of the instances to which this principle is now to be applied, we shall find very great variety in the condition of the exciters, and in the character of decomposition induced, according to circumstances, and to the nature of the material to which they are applied, and from which they arise. We have regarded the *specific* exciters of constitutional disease as acting only on a single element of a compound mass; but in reference to the putrefaction of external parts, we shall find them varying almost infinitely from those produced from, and capable of acting on, a single constituent of the tissues, to those involving more than one material, until they include the whole mass of the compound matters; we shall observe different conditions of decomposition induced upon similar materials by extraneous circumstances, and exciters emanating from them that are capable of reproducing the same condition. To take a familiar example,—if a cheese be divided into several portions, and each be placed under circumstances calculated differently to affect its decomposition, they will soon be found in very different conditions of decay. That which is kept moist and warm will have become absolutely putrid, while another, better preserved, will be blue-moulded, and a third, kept dry, will gradually crumble into dust. The connoisseur in cheese is very curious in producing exactly

the species of decay which best suits his palate by attention to such circumstances; but when he has thus once obtained a morsel exactly to his liking, he knows that it is not necessary to go through the same tedious and uncertain process to make another cheese succeed his favourite with the same flavour. He has only to choose one of similar character, and introduce portions of the old into incisions made in the new, and he may await with confidence the result of this practical propagation of a semi-specific eremacausis. So it appears to be with the different kinds of putrefaction capable of being induced in external wounds in the living body.

We have already alluded to one mode by which putrefaction may be induced on a wound, in the instance of the cook's hand or dissecting-room finger, by direct application of the exciter; but the same may also be effected indirectly by the absorption of putrid particles by the lungs: thus if a person on the verge of putrid typhoid fever receive a wound, it will be liable to take on putrefactive action. Bruised portions, of which the vital functions have been impaired, will acquire the tendency to putrescence from the active particles contained in the blood itself, and aided by exposure to the air, the edges of the wound will slough, and the putrefactive action be readily propagated along parts of low vitality, such as the sub-cutaneous tissues of the scalp. Erysipelas, with low irritative fever, will then be the consequence, just as we have seen ensue from putrefactive action propagated up the arm from wounds received in dissection. The putrid exhalations from this erysipelas being diffused in the atmosphere, and coming in contact with a wound in a more healthy person, propagate their own action there by direct application; thence it is again exhaled, till at length the whole air of a surgical ward is so contaminated that every wound or abrasion takes on the same character of disease. But it is not always the same character of putrescence that is thus engendered; local causes appear to exercise as much influence in its modification as we have seen to be the case in the decomposition of cheese; and just as one cupboard or cellar will make cheese ripen, while another, to all appearances similar, will make it rot, so will one ward often be found to give one character to stumps after amputation, and another a different one. In one, perhaps, they heal

kindly at first, but begin to ulcerate after the first dressing; in another, they become gangrenous; in another, without becoming sloughy, they are flabby and indisposed to heal—are watery and ichorous, as if the cellular tissue and the serous secretions were most in fault, a condition which appears peculiarly liable to extend itself to the divided veins. We have then phlebitis; and after one such case occurs in a ward, inflammation of every wounded vein appears to becomes endemic in that ward till whitewashing and other disinfecting processes are had recourse to.

The appearance of ulcers in hospital is an excellent indication of the healthiness of the wards, for after over-crowding or neglect of periodical purification, a change of weather will often be accompanied by the assumption of one general character in every abraded surface, or commencing in one case, it will soon spread to the others, whatever the origin of the sore or difference in the constitutions of the patients; and if they become foul, sloughy, phagedenic, or erysipelatous, they do so nearly alike. In some badly situated hospitals, such as the Hotel Dieu, which lies low upon the Seine, hospital gangrene is so liable to break out, that formerly, for whole seasons, every portion of the tissues exposed by wound or removal of the skin, took on putrefactive action, now dry and inodorous, now humid and fetid, but equally communicable by emanations, and every patient operated on died. There can, therefore, be no doubt that external circumstances may exercise as much influence in giving peculiarity of character to putrefactive action on living tissues exposed to their operation as we have found to be the case in cheese; and there is as little doubt that the species of decomposition so generated may be propagated by active particles from parts in such conditions, even beyond the influence of the circumstances by which they were originally produced, just as peculiarity of character is given to the decay of cheese by inoculation with a portion in that state brought from a distance. Some of these molecular exciters are more permanent than others, and some are more active, buoyant, and diffusible in the atmosphere, and more or less capable of attaching themselves to furniture, walls, floors, &c., and of there remaining dormant so long as they are dried up, but ready to resume their activity under the influence of moisture. For example,—some years ago the Manchester Infirmary was seldom

free from erysipelas, but by dry rubbing, instead of washing the floors, this disposition was greatly overcome; but this was an innovation strenuously opposed by the matron, and whenever an opportunity offered, she seized upon it to have the floors of the wards washed, the invariable consequence of which was a fresh outbreak of erysipelas where none previously existed. Similar facts are on record of the repeated outbreak of contagious ophthalmia and dysentery, where it was believed that the tendency had been overcome, and of these diseases being conveyed into barracks by a regiment, and the regiment which succeeded in their tour of occupancy becoming infected, though the contagion had evidently not been indigenous there but imported. We have had both ophthalmia and dysentery introduced into our wards by the inhabitants of cellars, and seen it spread rapidly where it did not exist previous to the admission of such patients; but these are contagious diseases, of a more specific character than those which have previously occupied our attention, in which the general materials of the frame were affected by gangrene or ulceration, and require to be distinguished from them as well as from specific fever or constitutional disease, for they operate on an external secretion, not on matters circulating in the blood, nor even directly on the actual structures of the body.

It would appear that the cause of contagious ophthalmia is a particular rearrangement of the constituent elements of the mucus of the eye, produced by the contact of particles emanating from the same secretion while undergoing a special kind of decomposition. The effect of its application is change of the bland lubricating fluid externally, similar to that which takes place internally in the *materies* of small-pox in the blood,—viz., its conversion to an irritating poison, which causes inflammation of the conjunctiva, so that it is not, in fact, a specific inflammation, but inflammation produced by the presence of a specific irritant. But this exciter can act on no mucus in the body of different composition; it does not convert that of the nares, or fauces, or digestive organs, with which it necessarily comes in contact, neither does it affect the elements of the mucus of the eye as they exist in the blood, nor till they are actually secreted as mucus, otherwise it would become a constitutional disease, probably an exanthematous fever. The irritation produces inflammation of the secreting membrane,

and thereby changes the secretion into pus, and so puts a termination to the disease by stopping the supply of that particular secretion, on which alone the exciter can operate. We cure this disease, artificially, by the frequent application of powerful antiseptics. We know, too, by experience that the exciter to this particular state of decomposition in the lubricating fluid of the eye is very subtile, and capable of producing its effects on its own *materies* in the eyes of others, even after having been wafted by the air to great distances, and after it has lain long inactive.

In gonorrhœa the cause is similar, but the specific transmutation effected by the exciter appears to be confined to the secretions from the genito-urinary mucous membrane, and not to be capable of extending its action into that of the bladder. Here, also, the natural cure is effected by change in the nature of the secretion produced by the inflammation induced by the presence of the irritant; and here, also, the artificial cure is effected by the use of antiseptic applications.*

The only mucus in the body upon which the gonorrhœal exciter is capable of operating, except that of the urethra, is the secretion of the eye, causing gonorrhœal ophthalmia by its contact. We have remarked upon the inability of this exciter to produce its specific effect on the blood from which its mucus is formed, yet there is some reason to believe that the integral particles of its exciter may circulate in the blood without losing their activity, and produce their specific effect when evolved along with the particular secretions which it is capable of affecting; for it would appear that gonorrhœal matter introduced into the rectum is capable of inducing urethral gonorrhœa as well as gonorrhœal ophthalmia without direct contact.

The possibility of active putrescent particles being circulated along with the blood and expelled with the secretions unchanged, and still capable of acting as exciters, was formerly alluded to, and affords the most probable explanation of the effects produced in

* May not the above suggest the impropriety of the early use of emollient or very weak injections, as liable to convey the specific cause of the inflammation to the posterior portion of the canal?—and does it not argue in favour of the earliest possible application of antiseptic injections as powerful as can be borne, but confined only to the anterior portion of the urethra?—at the same time adopting the necessary remedies for local inflammation, whether induced by the specific irritant or by the injection.

other diseases by contagious particles which appear to have no means of entering the system but by respiration, and yet, without affecting the mass of the blood, operate on parts or secretions to which their application cannot otherwise be traced, as in puerperal fever and contagious dysentery. There is reason to believe that the concentrated exhalations from putrid exuviæ not unfrequently become a local cause of dysentery, without the aid of epidemic influence; at least cases of very acute dysentery, of highly contagious character, are frequently met with in cellars with open soughs or contiguous to foul necessaries. This may, perhaps, be explained by the exhalations from putrid intestinal mucus, when absorbed into the blood and expelled into the colon in a state of activity, inducing their own action in the mucus contained in the intestinal canal; for it would be difficult to explain how a patient, taken from such a locality and placed in the ward of an hospital, should infect those in the next beds, on any other supposition than that the putrescent particles evolved from that patient, or the dejections, were absorbed with the breath and excreted into the bowels, and there converted the natural lubricating mucus of the colon into an irritant capable of inducing ulceration of the membrane. It may appear a more simple explanation to suppose the active particles swallowed with the saliva; but the extraordinary power possessed by the stomach to destroy putrefactive action, and the fact that it is the colon and not the small intestines or stomach that is generally affected in this form of disease, somewhat militate against that opinion.

If it be allowable to continue such speculations, they may suggest an explanation of the almost incredible, yet too true, accounts we meet with of the operation of putrefactive exciters upon the thousand lacerated uterine veins of lying-in women, for it is recorded that not only direct contamination from the hand of the operating midwife previously engaged with a case of puerperal fever or other contagious putrid disease, but even the presence in the room of persons who have recently visited those suffering from gangrene, erysipelas, phlebitis, typhoid fever, &c., or who have attended an anatomical demonstration without change of dress, has communicated this fatal disease to their patient without manual contact.

If we attempt to trace the operation of this putrefactive cause,

whether directly applied or reaching the susceptible part only through the circulation, we can scarcely avoid perceiving in the inflamed veins an analogy with gonorrhœa. Their inner coats are lubricated by a secretion peculiar to themselves; this, when exposed to the air, is apparently so susceptible of chemical alteration that almost any active putrescent particle will excite its decomposition and conversion, this spreads along the tubes from their ruptured orifices, the same irritating effects are produced as we perceive in the urethra, viz., inflammation and alteration of the secretion into pus, or plastic lymph and adhesion of the coats; the pus so formed circulates with the blood, and, obeying the law previously alluded to, is thrown out of the circulation like other noxious materials, and forms deposits in the lungs or joints, or destroys life.

This is certainly not the view usually entertained of the progress of inflammation along the veins, which is held to depend upon what Mr. Hunter has denominated continuous inflammation; and I may be too bold in suggesting the possibility that the progress of inflammatory action along serous and mucous membranes, in certain forms of bronchitis, peritonitis, &c., may sometimes depend more upon the condition of their secretions than originally on any peculiar activity of their vessels; yet the violent effects upon interior organs, produced by puncture of the hand, received in examining bodies very recently dead of acute diseases, appear to give some countenance to such speculations, though I am sensible that they are too unsubstantiable to be further insisted upon at present.

I have now only to apologise for the length to which this paper has extended, and especially to request your indulgence for such immature remarks as a desire to embrace the whole subject has led me into. I am not so vain as to believe that I have contributed novelty to the subject, nor sanguine enough to suppose that all I have advanced will meet your approval. My object will have been fully attained, if my attempts at definition of the several causes that conduce to the production and the variety of pestilence, fever, and other diseases, succeed in giving rise to reflection on a subject which, at the present moment, it is particularly desirable that the medical profession should well consider, and unite in their conclusions. If it shall appear that the sub-division of the causes of

general disease be actually such as they have been here considered, the hope may be indulged, that the ultra-contagionists and anti-contagionists may find, in the combination of epidemic with putrid fever, a common ground on which to adjust their differences, for it cannot but be considered highly detrimental to the respect due to the profession, that opinions apparently wholly irreconcileable should be held by many of its members on a subject so important as contagion.

If, in the discussion of these questions, I have appeared to have occasionally overstepped the bounds of ascertained knowledge, and especially in the latter part of the paper to have ventured on subjects beyond my ability, the kindness with which you have listened to me convinces me of your approval of the intention at least, if not of the execution, of my task, and that you are disposed to view with leniency any errors I may have fallen into in endeavouring to apply to the elucidation of some of the mysteries of disease a great, though only recently discovered, law of nature, to which it would appear that every product of vitality must ultimately submit.

ON THE

CAUSES OF MORTALITY

AFTER

AMPUTATION OF THE LIMBS.

BY J. H. JAMES, F.R.C.S.,

Surgeon to the Devon and Exeter Hospital, and Consulting Surgeon to the Exeter Dispensary.

The subject of amputation is one which for centuries has in no ordinary degree engaged the attention of surgeons; nevertheless, it has been left to comparatively modern times to estimate, with any approach to correctness, its true relations to life or death. It is since a very recent period we were made fully aware that this operation, till then not regarded as one of remarkable fatality (at least in civil practice), is really more so than the much-dreaded one of lithotomy.* This, however, does not equally apply to military surgery, for its records have always abounded with proofs to the contrary.

The amount of the mortality not duly estimated till of late years, in civil practice.

Mr. Alcock, whose tables are of particular value, from the circumstance that all the cases came more immediately under his own inspection, justly observes, "That a rare combination of circumstances is required to render the observation and registry of a large number of facts, accurately and fully defined, possible;" and he truly states, "that military surgeons have commonly too many obligations imperative upon them to be able to devote the time and concentrated attention necessary." Still, it must be gratefully acknowledged, that it is to military surgeons we have

* Mr. Philips's first paper in the *Medical Gazette*, Nov 14th 1837.

hitherto owed the largest amount of valuable information on this subject; and, among the British, I may especially mention Mr. Guthrie. From the circumstances alluded to, it has probably happened that few of the tables we possess fulfil all the conditions we might desire; and it may be permitted to allude to some points in which they are more or less defective, not, however, confining myself to military tables alone. In some we find amputations of the upper and lower extremities set forth, without distinction of thigh and leg, arm and fore-arm; in some, secondary amputations, truly so called, *i.e.*, for injuries, are not distinguished from those for diseases,—a very important error. In very few, if any, are intermediate amputations specified; often a difficult task, it must be admitted. In amputations for accidents, the particular kind of injury frequently is not stated; for disease, the nature thereof is often not particularized; when death has ensued, the intermediate cause, although frequently given, is also often omitted. To the tables lately published by Dr. Laurie,* Dr. Potter,† Mr. South,‡ and Dr. Steele,§ these objections apply with much less force, to some not at all; and there can be little doubt that a large amount of accurate information will be supplied ere long.

Difficulty in ascertaining the true ratio of mortality.

Principal defects in many of the tables.

More than thirty years' experience, as the surgeon of a large provincial hospital, has enabled me to collect an extensive record of operations of all classes, and among them amputations, of course, form a considerable proportion. The evident desire of the profession to obtain all the information which can be supplied on this subject, has led me to examine that series; and the belief that I may be enabled to contribute some suggestions, usefully bearing on it, has induced me to offer this communication. The accompanying tables contain the result of that experience, but they are defective in many respects. They are constructed from notes of cases, made with no design of publication, and not compiled from any public register; for, until within a very few years (the result of which I have also given) unfortunately none has been kept at our

* *Medical Gazette*, vol. xxvii.

† *Medico-Chirurgical Transactions*, vol. vi. New Series.

‡ Translation of Chelius, with Commentary.

§ *Edinburgh Journal*, No. 146. 1849.

hospital; an observation which applies to most others, as stated by Mr. Phillips; still they contain a considerable amount of valuable information, as I believe, and imperfect as they are, it is perhaps better to make such use of them as they may be fairly entitled to, than to throw them quite away. It may be a question whether I should have published them; there can be none, that it is too late in life to accumulate such an amount of fresh materials. To the tables (in detail, at the end) is appended an explanation of the circumstances of the several cases, which will test their *degree* of claim to statistic value; at all events, it will, I think, be conceded that they afford fair materials to reason upon, *in conjunction* with such data as other sources supply. They commence in the year 1816 and end in 1849, including an even number of 300. These do not comprise all that have been performed during the time alluded to, for there were three intervals when circumstances prevented my recording the cases which occurred, but it is very material that I should at once say, that every one which I have entered during the period stated, has been set forth, otherwise they would be vitiated altogether, for nothing can so much impeach the true value of any record as the suppression of a single fact. I may mention, that of the number, four were in private, but from the peculiar advantages our hospital patients possess, I do not think it would be worth while to exclude them, as I do not believe they were in any respect better off.

Imperfections of my own, and the cause.

Still they may serve as groundwork for reasoning, taken in conjunction with others.

They amount to 300, and include every case recorded in a given period.

Divided into two series, for injury and disease.

These cases I have divided into the two great series of amputations for injury and amputations for disease, which it is becoming the fashion to call pathological amputations; but I shall adhere to old terms, unless when convinced that modern ones are better. The one alluded to is neither shorter nor more definite; indeed, if its application be strictly examined, we shall be at some loss to know how the doctrine of diseases can, with any propriety, be converted into the diseases themselves.

The amputation for injuries,—"the surgical question of the age," as M. Malgaigne terms it,*—will be first considered. They

* *Medical Gazette*, p. 464.

amount to 68 primary and intermediate, and 26 secondary and intermediate. The numbers may not appear large, but yet, comparing them with those which have been recorded in other civil hospitals, they will be found considerable.

Supposing my own records were perfectly accurate, the numbers and results would stand thus:—

Table constructed chiefly from the experience of the Devon and Exeter Hospital, between the years 1816 *and* 1849.

General table of 300 cases.

TABLE I.

	Primary and intermediate.		Secondary and intermediate.		For diseases.		Total.
	No.	*Deaths.*	*No.*	*Deaths.*	*No.*	*Deaths.*	
Thigh	13	8	15	5	118	11	
Leg	18	7	5	1	57	5	
Arm, including three of the shoulder joint, which recovered	19	3	4	1	18	1	
Forearm . . .	18	0	2	0	13	1	
	68	18	26	7	206	18	300

* The proportionate mortality after amputations for disease will appear small, so small, that when coupled with the circumstances I have already stated, it may lead to more doubt than perhaps ought to exist of the average ratio of mortality in our hospital. I am, however, inclined to believe that it is not at all less than facts would prove; and the better to submit this matter to the judgment of those who may take the trouble of considering it, I here subjoin the results of our amputations *since they were regularly registered*:—

Results of amputations registered at the Devon and Exeter Hospital, from Agril 12*th*, 1847, *to November* 3*rd*, 1849.

	Primary.			Secondary.			For disease.		
	No.	*Deaths.*	*Recov.*	*No.*	*Deaths.*	*Recov.*	*No.*	*Deaths.*	*Recov.*
Thigh . .	1	–	1	–	–	–	9	–	9
Leg . . .	4	1	3	1	–	1	6	1	5
Arm . .	1	–	1	–	–	–	–	–	–
Fore-arm .	1	–	1	2	–	2	1	–	1
	7	1	6	3	–	3	16	1	15

Total number, 27. (The result in one case is not entered.) One case is out of danger, but under treatment; I have entered him among the recoveries.

In the foregoing list are not included amputations of any portions of the hands or feet, nor, therefore, Chopart's operation, which I have twice performed with success.

I have here inserted the results of amputations for disease, as in the course of this communication I shall have occasion to refer to them. But my object at present is to investigate the subject of primary amputations; and, in order to bring both the number of our operations of this class, as well as the results, into comparison with those recently published of other civil hospitals, I shall proceed to give the following tables.

Tables of primary amputations.

Parisian, from Malgaigne.

In "An exact Extract of all the Amputations practised in Paris for Traumatic Lesions, during a period of ten years, from 1836 to 1846," given by Malgaigne,* it appears that there were :—

	No.	*Deaths.*
"Thigh	44 ..	34
Leg	67 ..	42
Arm and Shoulder	36 ..	24
Fore-arm . . .	10 ..	2
	157 ..	102"

Simpson's, from thirty British hospitals, without anæsthesia.

Professor Simpson having collected the results of *primary* amputations in thirty different British hospitals, chiefly provincial, between the years 1840 and 1847,† without anæsthesia, gives them as follows :—

	No.	*Deaths.*
Thigh .	73 ..	45
Leg . .	80 ..	26
Arm . .	77 ..	17
	130 ..	88

* Extracted from the *Medical Gazette*, Sept. 15th, 1848.

† It must not be understood that this includes by any means the whole number of primary amputations performed at all these hospitals during seven years, as the period given varies much in most of them. Simpson "On Amputation." Table v., p. 11.

From forty-nine, with anæsthesia.

He also collected subsequently the results of the experience of forty-nine British hospitals, under anæsthesia, as follows. (Table i., p. 7.)

	Primary amputations.	
	No.	*Deaths.*
Thigh .	24 ..	12
Leg . .	32 ..	9
Arm . .	17 ..	4
	73 ..	25

But to this table we must refer with some hesitation, for it is probable that some of the worst cases which occurred in these hospitals, not having been submitted to anæsthesia, do not appear in the returns. Professor Simpson's tables include *all* amputations. My reasons for stating the primary only, must be obvious.

London University CollegeHospital. Dr. Potter.

Dr. Potter, whose valuable life fell an early sacrifice to the duties of our profession, has given the results of sixty-six cases of amputation of all kinds, during a period of six years and a half, at the London University Hospital. They offer only ten cases and three deaths of primary amputations of the different limbs, but they are reported with complete accuracy.*

St.Thomas's. Mr. South.

Mr. South has also given a very full statement of the cases which occurred in his own practice at St. Thomas's Hospital during six years, *i.e.*, from 1835 to 1840 inclusive; they amount to fifty-four of all kinds. Of these, primary, were—

	Primary amputations.	
	No.	*Deaths.*
Thigh .	5 ..	5
Leg . .	9 ..	2
Arm . .	6 ..	0
Fore-arm	1 ..	0
	21 ..	7 †

* *Medico-Chirurgical Transactions*, vol. xxiv., p. 155.

† Translation of Chelius, with Commentary, vol ii., p. 911.

From various sources. Mr. Phillips.

Mr. Phillips, who first called the attention of surgeons to the results of amputation in civil practice, has collected some returns which, from the number of cases they include, it is right to give, but qualified very justly by his own remark,—"I by no means think that the results furnished by such data will fairly represent the mortality."

	Primary amputations.	
	No.	*Deaths.*
Thigh .	245 ..	176
Leg . .	204 ..	88
Arm . .	164 ..	49
	613 ..	313

*

From the Glasgow Infirmary.

Dr. Laurie and Dr. Steele have given exceedingly valuable tables of the results of amputation in the Glasgow Infirmary, for more than half a century, but it materially lessens their value that, from local circumstances, operations of every kind appear to have been attended with a more than usual degree of fatality, so much so that the Governors have been lately induced to erect a separate building, for the purpose of trying how such mortality might be diminished.

Experience of the Glasgow Infirmary from 1794 *to* 1838.

Dr. Laurie.

	Primary amputations.	
	No.	*Deaths.*
Thigh	11 ..	11
Leg	22 ..	15
Arm and Shoulder	26 ..	13
Fore-arm . . .	15 ..	0
	74 ..	39

†

These, I apprehend, are not the whole number of cases treated, but such as Dr. Laurie could depend upon.

* *Medical Gazette*, vol. xxxiii., p. 804.

† *Medical Gazette*, vol. 27, p. 400.

Dr. Steele, in a valuable paper contained in the *Edinburgh Journal*, clxxxiii., has continued the series, and the following is the result:—

Dr. Steele.

	Primary amputations.		
	No.		*Deaths.*
Thigh .	32	..	21
Leg . .	53	..	22
Arm . .	49	..	15
Fore-arm	35	..	4
	169	..	62

These tables, together with my own, will suffice to supply materials for the consideration of those points which it will be the first object of this paper to discuss; but it will not be deemed an unnatural course for me to adopt my own as the groundwork, and refer to these in proof of any positions which may require it. I shall, therefore, re-cast my first table with reference to primary and intermediate amputations only, which will then stand as follows:—

TABLE II.

My own. First division. Primary with intermediate

		Primary and intermediate amputations.*		
		No.		*Deaths.*
Thigh .	Pri.	10	..	6
„ .	Int.	3	..	2
Leg . .	Pri.	17	..	6
„ .	Int.	1	..	1
Arm . .	Pri.	19	..	3
Fore-arm	Pri.	18	..	0
		68	..	18

* The number of intermediate amputations appeared too small to arrange separately; I therefore threw into this table those which approached most to the character of primary; the others in a similar way I have arranged with secondary.

The mortality after primary amputations,—the causes to be sought.

Having thus set forth the bases of my reasoning, I shall next proceed to a deliberate enquiry into the causes of the remarkable mortality of primary, I may also add, of secondary amputations, as contrasted with those for disease; an enquiry which, as far as I know, has never been systematically attempted, and therefore every allowance must be made, both on the score of its novelty and its difficulty. In the first place, I shall consider the *nature of the injuries* themselves, which has a most material influence on the whole question, and shall therefore state what, upon examination, appears to be the case in this respect as regards my own tables.

Partly in the nature of the injuries themselves.

In the fore-arm the injuries were chiefly occasioned by the bursting of guns, the discharge of small shot through the hand, or laceration by mills of different kinds. In the upper arm a large proportion of the cases also resulted from mill accidents, in which the arm was lacerated or crushed, or both, and in many instances high up.

In the leg the injury has commonly been from heavily-loaded waggons passing over it, or the foot, and consequently crushing it; some from persons jumping from a height; some from the explosion of mines; from heavy weights falling upon the limb; or from crushings in railways. In the thigh the same class of injuries has mostly obtained. The different modes in which these various injuries affect the results, will be hereafter stated.

How far affected by the condition of the recipient.

The subjects of primary amputations, commonly in full health.

But, to return to the more immediate causes of death. Of the great excess of mortality after amputations for injury, as compared with those for disease, neither my own tables, nor any others, will leave the slightest doubt. The question is, why is this so? The subjects of operation are commonly of a much more hopeful description than in the latter class. The operation is the same; wherefore the difference?

Mr. Hunter's axiom on this point, considered.

Mr. Hunter laid down an axiom which can scarcely be deemed the true* explanation, that health does not brook disease well;† a doctrine, which he expressly

* "Fundamental Principles of Information," vol. i., p. 411. "On Gun-shot Wounds," vol. ii., pp. 488, 489, *et seq.*

† The germs of this doctrine may be found in the controversy so ably sustained between the eminent surgeons of France in the last century, *vide* "Boucher, in Mem de l'Academie," vol. vi., *et alibi.*

applies to the question of primary amputations, and it has largely influenced the judgment of surgeons. Two circumstances demand that some enquiry should be made into the validity of this opinion; one, that the facts, at first sight appear to countenance it; another, that any opinion proceeding from such a gifted mind deserves consideration.

In examining the probable foundation for it, perhaps it is not too much to say, that he was led into an error by a too limited view of the matter. The weight of authority at the time he wrote was adverse to primary, and favourable to secondary amputations. His own experience in military surgery was too limited to enable him to form any sufficient judgment. Secondary amputations in civil practice, and performed under *favourable* circumstances, were and are, on the whole, attended with less mortality than primary, (as I may be able to show); and it is probable that, without considering the matter in *all* its bearings, he formed this conclusion.

Not well-founded.

There is, however, one circumstance alone, which would, in my judgment, show that Mr. Hunter's axiom is not well-founded; it is the fact, that many other operations, if performed on the healthy, are attended with better results than in the opposite condition; this may be urged especially with reference to hernia, the removal of tumours, lithotomy, &c.

But although health must be deemed, *cæt. par.*, a favourable circumstance, as regards this and all other operations, yet, if we go further, and compare the results of primary amputations for injury with those performed for disease, the fact is too well established to admit of doubt, that the balance is much against the former; and that, if a soldier, or a robust and healthy labourer, have their limbs mangled by shot, crushed by waggons, or torn by machinery, and amputation is at once resorted to, the chances are more adverse than if the same limbs are amputated for the diseases which befal the feeble, sickly, or aged inhabitants either of town or country, though worn down by pain and suffering, by scrofula, or other debilitating diseases. It must be allowed, that it is an important object of enquiry to ascertain, by careful examination of the facts, and if it may be, by legitimate deduction, *the real cause or causes of the difference.* In arguing this question,

Yet amputations performed for disease on sickly persons are very much less fatal than for injury on the healthy.

I shall chiefly refer to the results of my own experience, and it will be found that in most respects this is not at variance with the facts stated by others.

The first point will be to investigate the more immediate causes of death in the class of primary, and early intermediate, amputations; and it will then be seen that most of them do not apply to cases of amputation for disease. The enquiry will further tend to show the relative importance of each of these causes; and I will now analyze, in a brief table, the primary and intermediate amputations I have given.

On enquiry it will be found that the chief causes of death after amputations for injury do not operate on those for disease.

TABLE III.

		Died from shock.	Died from secondary processes.	TOTAL.
Of amputations of the thigh:—				
Primary were .	10	3	3	
Intermediate .	3	1	1	
Of the leg:—				
Primary were .	17	2	4	
Intermediate .	1	–	1	
Of the arm:—				
Primary . . .	19	1	2	
Of the fore-arm:—				
Primary . . .	18	–	–	
	68	7	11	18*

It thus appears, that the direct and destructive impression, which has been designated by the term *shock*, has caused a large

* Dr. Laurie has analyzed the causes of death in seventy-three cases of amputation, p. 403; of which thirty-two were primary (he makes no distinction of intermediate), and of them five only are attributed to shock, twenty-six to secondary processes, one to tetanus; but, unfortunately, no distinction is made of the limbs in each case, as referable to primary, as distinct from secondary or for disease. The large excess of mortality from secondary processes, is probably attributable to the unfavourable air of that hospital.

First, cause of death after severe injuries, whether with amputation or without, is *shock*.

proportion of the fatality of these amputations,* and the fact agrees in a great degree with those related by other more extensive observers, but it may be permitted me to pause for a moment on this important subject. Whether amputation be performed or not, death often results from injuries, either immediately, from the impression made on the system, or if not at once destructive, from its influence continuing to increase till death occurs, the injured part still remaining in connection with the body, and this influence perhaps further increased by hæmorrhage, cold, or other depressing circumstances. Such a circumstance is amputation, and if performed while the state of collapse continues, it is a matter of general assent that it is likely to augment the tendency to death; (yet this is not always so, and I have known it save a patient in whom the symptoms of collapse were increasing, *maugrè* every effort to overcome them.) It may also renew the collapse, when the patient is rallying from it, while, if too long delayed, it may be useless from other causes, as the results of intermediate amputations will show. How many of the cases which perished from shock after amputation would have also perished from the same cause without it, cannot be ascertained, but I shall hereafter revert to the point.

The severance of the injured parts may lessen or increase the effect of shock.

On the other hand, if the additional shock of amputation is, in some cases, calculated to sink the powers further, the severance of the injured part will lessen the influence of a most depressing sympathy, and it is thus often a difficult question to determine in which direction the hope of safety or the fear of death most lies. It is, however, of no small moment to consider the

* (Opus citat.) Dr. Laurie, struck, like myself, with the great excess of mortality in civil, as compared with Mr. Guthrie's returns of military practice, attributes it partly to a cause which I have enlarged upon in a future part of this paper, *i.e.*, the difference in the injuries submitted to amputation in the latter being often less severe; partly to the circumstance of delay and exhaustion subsequently to the receipt of the injury; and partly to the injury involving other parts of the body. The two latter causes are, in my belief, equally applicable to military practice, where circumstances often render immediate assistance impossible, and where the sufferers are not unfrequently the recipients of more injuries than one.

different degrees of influence which an injured limb may exert on the system. A limb may require amputation because a part has been fairly torn away by a cannon ball, or a bone been fractured by musket shot, because a principal vessel has been wounded or a joint opened; and yet, in all these cases, there may have been no great extent of damage to the soft parts and *nerves*; no extensive disorganization, in short, of parts remaining in connection with the body, such as exist when a limb has been crushed, torn, or mashed by mills, cannon balls, wheels of heavy waggons, powerful machinery, &c.* This matter, perhaps, has not been *sufficiently* considered. Many years since some very interesting experiments were made by Le Gallois, in France, and Wilson Phillip, in England, (with no reference to this point), which, however, prove in a very remarkable manner, the extremely depressing influence of a *crushed* state of the *spinal chord*, as contrasted with the mere severance or simple removal. The argument may be applied to those injuries of the extremities whose *quota* of the nervous system, if I may be allowed the expression, is extensively crushed or torn, and the removal of their influence by amputation, may more than counterbalance the effect of the operation in such states of the limbs.

The effects of shock depend much upon the actual condition of the limbs, and that on the nature of the injury.

Experiments of Le Gallois and Wilson Phillip, which prove the very depressing effects of a crushed state of the spinal chord. This, by fair reasoning, may be applied to every part of the nervous system, and consequently to these cases.

The sympathy of the whole with every part, is a subject well understood; but the consciousness (if the expression may be used) of ability or inability to repair an injury, and the results, are also deserving deep attention. This consciousness operates in every abnormal state of the body. It of course did not escape the penetration of Mr. Hunter; but even he has scarcely done it full justice. It would lead me too far to enter largely upon it; but I may mention one or two facts which will explain my own views. A man shall have fractured the lower portion of the cervical spine; respiration, circulation, and digestion, shall go on with little disturbance,

Injuries, by sympathy influence the whole system; that becomes conscious of its degree of ability to repair them.

Instances.

* We find that not only the kind of injury, but the *part*, materially modify the effect. Such injuries of the lower extremities, whether amputated or not, in a large proportion prove fatal; of the upper, especially of the fore-arm, rarely.

his intellectual powers be unaltered, no lesion has occurred immediately incompatible with life, he neither dies of shock, nor hæmorrhage, nor inflammation, *but* he dies almost certainly within three or four days, without an effort or struggle, or any change which indicates speedy dissolution,—he dies from the system being conscious* of an irreparable injury. In contrast with this, is a phenomenon which also often occurs;—as an example, I may mention that the efforts of the uterus shall have ceased after long exertion, yet, if the forceps are brought to aid, those efforts will be powerfully renewed. They ceased, not from absolute want of power, but from a consciousness of inability to accomplish their task unassisted; and they are renewed because there is an instinctive feeling that the effects of that aid will render them efficient for the purpose. It is not pain that excites them. Probably no accident, no disease befals the body, without occasioning what is well denominated sympathy, it may be added, without a *certain consciousness in the system of the task it has to perform,* and its ability to perform it.

Timely aid will impart fresh vigour, by renewing the consciousness of ability.

But to return: although a large number of cases of amputation for injury die from *immediate* shock, yet, *if we substract these,* we shall still find that the proportion proving fatal is far greater than when performed for disease; thus, of the thirteen cases of thigh amputations (primary and intermediate), four died from the secondary consequences; whereas, out of 118 thigh amputations for disease (which I propose to detail at a future period), only eleven died. In the first case, the proportion is 4:13, in the second, 1:10$\frac{8}{11}$. Again, of eighteen leg amputations (primary and intermediate) three died from secondary consequences; of fifty-seven for disease, only five. The proportions, again, are, 1:6 and 1:11 respectively. The difference in the upper extremities is not so great.

After deducting the cases which die from the *immediate* effects of shock, amputations for injury still much more fatal than for disease, from the secondary processes.

Assuming, then, that my tables represent, if not quite accurately,

* It is very remarkable in some cases, how a similar consciousness exists, even in the intellectual being. While some live against every probability, others die, when nothing warrants apprehension, but they will say that they are certain of death, and it befals them.

yet sufficiently for the purpose, the difference in the results of amputations performed for injury, or for disease,* I shall next proceed to follow out, under the head of secondary consequences, the causes of this greater mortality. These secondary consequences are, sloughing and bad suppuration in the part, irritative fever, secondary inflammation, phlebitis, &c. &c., in the system; tetanus must be mentioned, but, although a frequent cause of death in all injuries, it is not especially the result of amputations.† These consequences do also occur, more or less, after amputations for diseases, but evidently less frequently or less fatally.

First, from the amputation being often performed through injured parts.

Now, the first point of difference is this, that in many amputations for injury, the operation is performed through the *injured parts*, and I may observe that this is much more frequently the case in the thigh than elsewhere; and thigh amputations are by far the most fatal, as we well know. In some instances the surgeon has no alternative but to carry his incisions through injured parts; but I may here, with great deference, submit that this is often done when not absolutely necessary, from an opinion which has perhaps been rather too hastily adopted. Amputations for injury in the upper and middle thirds of the thigh are much more frequently fatal than in the lower. Facts prove this to be the case, and it has been assumed that they are necessarily so, although no intelligible cause has hitherto been assigned for the opinion; but the practice, in a large proportion of cases, has been founded upon it, *i.e.*, to amputate in the lower third. If, however, it should appear that the greater fatality arises, not from the

This occurs more frequently in the thigh.

Is the probable cause of the much higher mortality of amputations in the upper portions of the thigh.

* By far the most extensive, and, in many respects, valuable reports with respect to the results of amputation for disease, as distinguished from those for injury, are Dr. Laurie's, published in the *Medical Gazette*, vol. xxvii. The amount of mortality they exhibit, in the practice of the Glasgow Infirmary, is much larger in proportion than my own; but this appears to have been made up, in a great degree, by a very unusual excess of mortality after amputation of the leg (nearly one half), and it must further be borne in mind, that the mortality in the Glasgow Infirmary, after all operations, was remarkably great, as I have elsewhere mentioned, from circnmstances of locality, in all probability, as indeed Dr. Laurie freely allows.

† Out of the sixty-eight amputations, it occurred twice, and fatally; they were both leg amputations.

amputation being performed in the particular region, but, when there performed, it is because the parts are so extensively injured as to render it impossible to amputate otherwise than high, and even then, it may be supposed, often through unsound parts; one great cause of this fatality in high amputations may admit of an intelligible explanation, and a practical inference might be deduced, *i.e.*, that, disregarding any prepossession as to the fatality of such operation, it would be better to amputate high in the limb, through sound parts, than lower, where they are injured. It may be said, that I have no sufficient grounds for objecting to a received opinion, and explaining the facts, as I have done; but I would submit that the point may be put to the test of experience. It is often requisite in amputations for disease to go high up. Are these cases more fatal than others, and, if so, in what proportion? As far as my own observation goes, they are not so; but this might in no long time be ascertained.

In amputations for disease, unsound parts often divided, but the condition of those parts, as regards the ability to repair, intrinsically different.

It may be said, when we institute a comparison between amputations for injury and for disease, especially of the thigh, that in the latter case also the knife often goes through unsound parts; but let us contrast the *different kind of unsoundness*. It may divide parts, it is true, more or less inflamed, in which lymph,—nay, in which pus is effused; but if we reflect on the nature of these processes, we shall at once see that these are merely *natural efforts at restoration*, and the parts are both *disposed* and often able to repair; but in the case of injury, they are torn, mashed, disorganized,—greatly disqualified for such purposes.*

Secondly, the effects of shock are not confined to the immediate impression, but

The *immediate* effects of the preceding circumstances, *i.e.*, shock, on the one hand, and the consequences arising from amputation through parts whose organization and vital powers are impaired, on the other, in producing a great amount of mortality, will be doubted

* Mr. Syme has proposed, as a cause of the remarkable mortality of amputations in the middle of the thigh, the injury inflicted on the medullary membrane; but, independent of other arguments which oppose this opinion, I may mention that the mortality from primary amputations is *proportionably* great in *all* the limbs.

by no one. If, however, I am not mistaken, there is another cause which greatly influences the secondary processes, and it is not only in cases of amputation that the changes, to which I shall presently allude, ensue, but in many other instances, as in compound fractures, severe lacerations, extensive burns, &c. The first symptoms of shock may subside, still we have those of a bad type *in individuals previously healthy;* there is a great tendency to secondary inflammations and suppurations, to phlebitis, and the whole class of spreading inflammations. In injuries unamputated, and in amputations through unsound parts, it might be supposed that the continuance of the connection of the injured parts with the body might be the cause; but I believe I am justified in saying that it often occurs when this is out of the question, where the amputation has been performed above the injury in structures that are *sound.* Why is this? Why does a man die, whose thigh is amputated for an injured foot or leg, although in good health, while a sickly man shall live, most probably, when a similar operation is performed for a diseased joint?

in all cases of injury, whether amputation is performed or not, powerfully influence the secondary processes.

Proof of this is afforded by cases of amputation where immediately performed, and through sound parts.

The immediate effects of violent injury are impressed on every system in the body: the heart falters, the stomach rejects its contents, the liver ceases to secrete, or secretes perverted bile, the nervous system is beat down, and the countenance betrays the deep defailance; clammy sweats, tremors, and other consequences of nervous depression occur; but these all pass away,—these various systems, after awhile, often recover themselves; but still a tendency to diseased action remains, which did not exist before, and this tendency to diseased action is, I believe, produced by the impression made on the system at the time the injury was inflicted, and although the immediate effects, as mentioned above, may pass away, this tendency remains. Whence does this arise? I believe that it does arise from the changes wrought in the *blood* at the time the injury is inflicted, communicated originally through the nervous system, but persisting long after the direct operation of this cause has ceased. This is the real reason why the consecutive

Probable that this arises from changes wrought in the blood at the time the injury was inflicted, which changes are in their nature less transitory than in the other systems.

fever assumes that type, which, for want of a better term (and it is much to be regretted that we have not a better), we call irritation, but whose chief character is want of power. On this subject no one has entered with more philosophical views than Mr. Travers, but I cannot help thinking that the term, in all its phases, although first adopted by the highest authority, and sanctioned by use, is calculated to limit our view of the phenomena to the nervous system especially, to the exclusion of others which may be more really the cause. Be this as it may, the inflammations which occur in various parts will fail to be arrested, as usual, by the adhesive process, and will run into evil suppurations, which, once formed, are so often fatal. Out of a bad material nothing good can be wrought, and I believe that this is the case here. That the blood having once received an impression, or undergone a change, will long retain it, will hardly now be disputed, and everything argues in favour of its being so changed in these cases,—nothing more forcibly than the speedy decomposition of the bodies of persons who die in such a state. The effects of shock, then, may be considered in two points of view, both as *immediate* and *remote*. The immediate effects have been recognized by every surgeon, the remote but little. I should not, however, do justice to Mr. Alcock, if I did not state here, that he was fully cognizant of the remote effects of shock, but he imputes it to a different cause, I mean the state of the nervous system, p. 72, et seq. I am more inclined to attribute it to changes impressed on the blood, for reasons I shall state.

The effects of shock, then, to be considered as two-fold, —*immediate* and *remote*.

No greater authority can be adduced for the fact, that the blood and the general system exert a very powerful reciprocal influence, than that of Mr. Hunter, yet even he was not aware of many circumstances which now seem strongly to evince it. If anything, however, can show the fact in a more forcible manner than another, it is the phenomena consequent on venesection. Even while the blood flows, the *whole* becomes changed; the proportion of fibrine, of serum, of red globules, of serosity, varies in every successive portion that is taken; the period and force of the coagulation vary also every instant,—phenomena which can arise only from the impression continuously produced on the whole mass

Phenomena which evince the more permanent changes often wrought in the blood.

of blood by the hæmorrhage. But it does not stop here; changes not cognizable to the eye also are effected, and often become *permanent*. For example, a person labouring under a long-continued sub-acute inflammatory disease of the lungs, liver, brain, or other organ, if bled, shall, ere a few ounces have flowed, often experience a change in the condition of the inflamed part, nay, of the whole system, and will feel a relief which no diet, no medicine had previously wrought; and, that bleeding, although very moderate, will often effect a *permanent* alteration in maladies of weeks' and months' duration, long after the mere *quantity* lost has been again supplied.

If, then, such impressions can produce such changes, we may be well warranted in believing that a violence, such as these grave injuries I have described, may powerfully affect and pervert the whole mass,—may *disorganize* it, if I may so express myself. The effects resemble those of morbid poison introduced into it. It is not a mere depression of power, a loss of vitality; no amount of evacuation, no degree of exhaustion, will induce such a perverted state. A change ensues in every part of the body; the previously healthy man is converted into a mass of disease. Whether, in such injuries, the limb is separated from the body or not, the system thus changed must work out its own cure, aided by our efforts, as we best may render them.* It is thus that, intermediate amputations failing to change this condition, the patients rarely survive; but, when the powers of the system have conquered this morbid state, when the secretion of pus, and those which are natural, approach to the condition of health, however profuse and however exhausting they may be, the knife will, in a majority of cases, prove a remedy, and the mangled limb be separated with advantage, by secondary amputation.

In these cases of grave injury its state approaches to disorganization.

In cases of injury not involving amputation, although we may have the strongest reason for believing that the destructive changes

* A great many phenomena which are imputed to other causes, such as the supposed absorption of a septic principle for injuries attended with disorganization and consequent sphacelus, may be, with much probability, explained on the principle here advanced. It is clear that no other can explain those which equally occur when a limb has been immediately amputated in sound parts.

Cases of amputation through sound parts afford the best proofs of the fact, that the immediate effects of injury do not cease with the severance of the part, and support the opinion that the blood becomes changed.

described have been wrought in the system, and especially in the blood, by the *immediate* effects of such injury, we have no actual proof that it is so, because the injured parts still remain connected with the body, and, whatever symptoms occur, may be the result of the direct sympathy of the system with the part. The conclusion drawn is probable, but not absolute. When, however, we have such effects following amputation performed for *injuries* of the leg or arm, above the contiguous joint, and shortly after the accident, in parts *perfectly sound;* and, again, when the cause is *disease,* and the surgeon's power of election complete, if we find that *no* such consequences are prone to occur, or, at least, in any similar proportion, we have more conclusive data to work upon. As a question of general pathology it is important, and may throw light on many other morbid phenomena.*

I am aware that the severe consequences which follow injuries and amputations are explained on other grounds, and no doubt they are, in many instances, enhanced, it may be sometimes produced,

* In vol. xxxi. of the *Medico-Chirurgical Transactions* is a very interesting paper by Dr. Hodgkin, bearing on the morbid changes wrought in the blood by local injuries. It was mentioned to me in the summer of 1848, by my friend Dr. Theophilus Thomson, who, being in Exeter, happened to go round the hospital with me; and, in consequence of some remarks I made on the subject, he adverted to this paper of Dr. Hodgkin, recently read to the Medico-Chirurgical Society, but not then published, as I believe. This part of the present paper was then written, and I immediately showed it to Dr. Thomson, and obtained his permission to mention the circumstance, as otherwise it might appear that I had partly borrowed my opinion from another source. I may, however, observe, that although the same *general* principle will perhaps apply to both my own and Dr. Hodgkin's cases, the class and the progress of the symptoms described by him are very different. As regards the former, the injuries were comparatively *slight*, giving rise to fatal changes at *late* periods; in those I have mentioned, the injuries are most severe, the changes most sudden. Perhaps I may be allowed to add, that in these it is not easy to suppose the change is wrought in the mode suggested by that able pathologist, p. 295, *et seq.* The explanation he gives as regards those he describes may nevertheless be quite true. In a very able lecture by Dr. Todd,* analagous opinions as regards the influence of the blood produces on tetanus and other disorders, are advocated by him.

* Lumleian Lectures.

by the foul air of hospitals or other places, and it is a point to which I shall have occasion to revert; but they will and do occur when no such causes can operate, and the remarkable fact is, that they occur in so very much larger proportion after amputations for injuries than for disease, in the *same hospital*, which shows that the principal cause is not the condition of the air; and I may further observe that they rarely ensue (as all the tables show) after the minor case of amputations of the fore-arm for injury, which strongly evinces the truth of the position, that they are in reality the result of the impression communicated to the system, and are just *in proportion* to it.

Tainted air will powerfully influence the secondary processes, but the fact that amputations for diease are fatal in a much less proportion in the *same* hospital, shows that the argument may be pursued as regards these cases independently of this consideration.

SECONDARY AMPUTATIONS.

The next point to be considered is, the causes of mortality after secondary amputations. Nothing can differ more than the statements we have upon this point; some tables give a greater, some a less proportion of mortality after secondary than after primary. The first question is, what may be fairly deemed the true period of secondary amputation; the second, the causes which more or less influence the results at this period.

Second division. Causes of mortality after secondary amputations.

It may be assumed that primary amputations include those which are performed at any time subsequent to the receipt of the injury, but prior to the establishment of active inflammatory processes in the part, and corresponding sympathy in the system; that secondary include those when either purulent secretion is fully and normally established in the part, or the processes of sphacelus arrested, corresponding changes having taken place in the system. Again, that those amputations which take place in the intervening time are the intermediate, consequently there is a wide range during which they may occur;* and I believe, with Mr. Alcock,

What may be deemed secondary, what intermediate.

* I believe this statement agrees with the doctrine first laid down by Boucher, Mem. de l'Academie, tome vi., p. 120, and receives the sanction of other great authorities in military and civil practice.

Great differences in the reported results of secondary amputations, partly explicable by including the intermediate.

that one explanation of the discrepancy which exists between the reported mortality of secondary amputations by different surgeons, has arisen from the circumstance that in many cases these intermediate amputations have been classed under the head of secondary. It is very clear that, in proportion as the state of the system approaches more or less to that favourable condition which is selected for secondary amputation, so will the chance of success be enhanced or otherwise. I believe that when performed for spreading inflammatory sphacelus they rarely succeed, although some fortunate cases are related by Larrey,* Lawrence,† and others; but when rendered necessary by sphacelus, produced simply by impeded circulation, from the wound of an artery or vein, or from hæmorrhage (the result of such wound), they much more frequently answer. My own experience is too limited to allow me to draw any certain conclusion;‡ but perhaps the point cannot be better illustrated than by the statement given by Mr. Guthrie as to the results of certain cases after the battle of Salamanca. He states,§ "that of 150 unfortunate wounded Frenchmen, who could not be collected for surgical cure till the period of amputation had passed, forty-six had amputation performed, but of these (chiefly of the thigh, however,) six only were saved." He adds, that those who were not operated on shared no better fate.||

In what cases the latter succeed.

But commonly are very fatal.

* "Memoirs de la Chirurgie Militaire."

† *Medico-Chirurgical Transactions*, vol. vi.

‡ Of the intermediate amputations I have recorded, three were performed on the thigh on account of sphacelus; of these, one recovered, when it arose from the rupture of the femoral artery; the other two, which were traumatic, died. Of the leg, one was performed for profuse hæmorrhage, the stump being sloughy, and he died. These cases, being at an early period, I have given together with the primary. Two others, amputated at a later period, but before the true time of election arrived, (Nos. 151 and 166), I have given under secondary. In one, a lad of sixteen, there was a wound of the tibial artery, with sphacelus; in the other, a man of seventy, it was performed while sinking from the consequences of a wound of the knee-joint. The first of these certainly recovered, and I have little doubt the second was saved.

§ "On Gun-shot Wounds," p. 59.

|| Boucher also states, "Of the number of about 150 wounded, whose wounds were in the extremities, those whom we did not think it necessary to amputate at the first period, either recovered without our being obliged to have recourse to it subsequently, or succumbed to the violence of the symptoms in the second, without being able to reach the third." Vol. vi., p. 130, "Mem. de l'Academie."

Of the great mortality of primary, and more especially of intermediate amputations, there can be no doubt; of the comparative mortality of primary and secondary, there is, as I have stated, a good deal of discrepancy of opinion and statement, from the time of Faure and Boucher to the present period. It will be my next business to enquire into the sources of this discrepancy, and into the more immediate causes of mortality in secondary amputations.

General agreement as to the mortality of primary amputations. Great discrepancy as to secondary.

My own tables, as far as they go, show a less proportionate mortality in secondary than in primary amputations. From the reports of civil hospitals but limited data have as yet been supplied. The valuable report of Dr. Steele, from the Glasgow hospital, is extensive, and, from various causes, demands much attention, but evidently local circumstances have there exerted a very powerful influence. Again, in military hospitals similar circumstances often greatly affect the question. The subjects have (unlike those submitted to primary amputation) been, for the most part, long exposed to the influence of a vitiated air. Often, after a great battle, carried into such hospitals as the emergency alone has created,—churches, convents, and similar buildings; crowded together; poisoned by the atmosphere they breathe, in common with a vast number of other wounded men, and often subject to the influence of endemic or epidemic diseases, their fate is often determined by circumstances foreign to the operation itself. And here I cannot sufficiently commend the system which, from the foundation of our hospital, has been pursued as regards these cases, not only after operation, but before; namely, that they are in the first instance received in large and airy wards, indiscriminately with other cases of every description, so that they are little exposed to the emanations from accumulation of fevered and wounded patients; after the operation is performed, they are placed in smaller, separate, and most convenient wards, where they have a degree of attention on all hands which cannot be surpassed in favour of the highest ranks; are distracted by no groans of other sufferers, or alarmed by their illness

The mortality after secondary likely to be affected by various causes; one very important one, *the long sojourn* of the subjects in tainted air *prior* to the operation.

Great success which has attended the system pursued in this respect in the hospital of this city.

or their deaths. If (in addition to surgical care) pure air, kindness, and the absence of injurious causes, can contribute to the well-doing of patients under such circumstances, ours have been for more than a century most fortunate, and to this system of management I greatly attribute the degree of success we have obtained.*

Besides the influence of air and other causes, which will be readily admitted as valid, whenever the case is one of secondary amputation under favourable, as contrasted with those under opposite circumstances, there is another point which has, perhaps, not received its due share of attention as regards the results of civil compared with military practice. In the latter, the injuries which require primary amputation are, for the most part, inflicted by fire-arms; a large proportion compound fractures from *musketry*, and in these the injury is by no means equal in extent, and consequently in degree of shock, to that which occurs in those accidents which, in civil practice, are more generally submitted to amputation,—accidents chiefly arising from the crushing by heavy waggons, blocks of stone falling on the limb, explosions, or from machinery of various kinds, including those of rail-roads. These are similar in nature to the *graver* class of injuries which occur in warfare, from cannon shot, shells, and other explosives; and it would be matter of no surprise, if, on more accurate investigation, the greater number of successful cases of primary amputations in military practice were found to result from the former class, which are rather, perhaps, submitted to operation from circumstances of situation, and the impression which exists as to the consequences to be ultimately apprehended, than because there is an intrinsic evil, too great to be combatted at the moment, while in civil practice this description of case is more frequently reserved for treatment. In comparing, therefore, the results of the one or the other, I think due allowance should be made for the circumstances now adverted to.

The preceding cause, *i.e.*, tainted air, often applies in military practice, but another cause of the greater mortality reported in military returns of secondary as compared with primary, as well as the less mortality of primary in many cases, as compared with the primary in *civil* hospitals, is the greater proportion of severe injuries, which become the subjects of secondary amputation in general military hospitals, and of primary in civil.

* If I am correct in taking this view, it will afford a very strong reason for greater solicitude in future as to the carrying out this important point.

If, then, the results of military practice are liable to be affected by two such important causes as those I have mentioned, namely, first, the number of lighter cases submitted to primary amputation, which would have been placed under treatment in civil, while in the latter only the graver cases fall under the knife;—cases where both the *immediate* and *remote* effects of shock are powerfully adverse, and where injured parts are often left behind; and also, secondly, by the secondary amputations in military practice having been in many instances previously exposed to deleterious influences, quite extrinsic to the operation itself, we may be warranted in concluding that the greater fatality of primary amputations in civil practice, on the one hand, and, on the other, the greater success of secondary, can both be explained.

Instances of the great differences which exist in military practice.

The discrepancy in the results of military practice are great, and, that I may not be considered as overstating it, I shall briefly advert to a few authenticated facts, and these I would rather present as the statement of another than my own. I take, therefore, M. Malgaigne.* As instances of success, I may cite the following:—Percy, out of ninety-two amputations of all limbs, lost only six; Guthrie, at Thoulouse, nine out of forty-seven;† Larrey's military experience, a most extensive one, in various regions, afforded a proportion of three recoveries to two deaths;‡ while, on the other, hand, Bilguer says, "among a crowd of persons on whom, during the seven years' war, amputation was performed, scarcely were one or two saved." Faure, "after Fontenoy, ascertained that the success resulting from about 300 amputations was reduced to thirty or forty." In his own campaign in Poland, Malgaigne says he lost all his cases of amputation of the thigh who had fractures from gun-shot wounds.§ These results, he adds, were so contradictory that he was induced to make an exact extract of all the amputations practised in Paris for traumatic lesions, during a period of ten years, from 1836 to 1846, which I have previously quoted.‖ It can neither be supposed that these statements are liable to discredit,

* As extracted from a report in the *Medical Gazette*, Sept. 15th, 1848.

† I see Mr. Guthrie himself, in his Lectures, gives it as ten in forty-eight.

‡ This is the statement of his Aide-Major, M. Blandin.

§ Page 464. ‖ Page 53.

where the precise numbers are given, nor can it be doubted that some explanation of the enormous difference is required. How far that I have now submitted may be satisfactory, is for others to judge; but to the statements already quoted from Malgaigne, I shall add the following recent returns, to show how great the differences still continue to be, under, it may be presumed, considerable variation of circumstances, but with the same class of operators, and the same class of subjects:—"Primary operations performed on the field between June 21st and December 24th, 1813, in the army under the Duke of Wellington,—Lower extremities, 128, deaths, 19."* "Primary amputations performed in the British Legion at Saint Sebastian's, from May 5th, 1836, to June 10th, 1837, —Lower extremities, 20, deaths, 12."† In the returns from civil hospitals the proportions mainly agree; the great discrepancy in military practice may, perhaps, be explained on the grounds I have offered.

In civil hospitals the proportions mainly agree —at least the discrepancy is by no means so great.

I shall next proceed to analyze the results of my own tables of secondary amputations, with the object of pointing out the chief causes of mortality, (as in the first division;) stating, however, that I have not had the same means of ascertaining them as in the primary, since they are apt to terminate at more remote periods, when I had less power of observing them closely. The numbers stand thus:—

Table IV.

TABLE OF SECONDARY AMPUTATIONS.

Analysis of my own tables of secondary amputations.

	No.	*Deaths.*	*Uncertain.*
Thigh (Secondary) .	13 ..	5 ..	2‡
,, (Intermediate§)	2 ..	– ..	–
Leg . . .	5 ..	1 ..	–
Arm . . .	4 ..	1 ..	–
Fore-arm . .	2 ..	– ..	–
	26 ..	7 ..	2

* Guthrie "On Gun-shot Wounds," p. 42. † Alcock, p. 95.
‡ Nos. 50 and 83. § Nos. 151 and 156.

This return exhibits a very small proportion of secondary amputations (excepting the thigh) as compared with the primary, and also a smaller proportion of deaths; and, throwing them into a common table, the numbers will stand thus :—

TABLE V.

	Primary and Intermediate.			Secondary and Intermediate.		
	Cases.	*Deaths.*	*Recov.*	*Cases.*	*Deaths.*	*Recov.*
Thigh .	13	8	5	13	5	8
Leg . .	18	7	11	5	1	4
Arm . .	19	3	16	4	1	3
Fore-arm	18	0	18	2	–	2
	68	18	50	24	7	17

Comparison with primary.

Only thirteen cases of secondary amputation of the thigh are included in this table, because I feel so uncertain with respect to the results of two that I think it fair to strike them out.

Affords proof of the restorative powers in the upper extremities.

On comparing these tables, the first remark I should make, is, that of secondary amputations of the fore-arm *none*, of the arm *few*, appear; affording positive proof that injuries of the upper extremities which are reserved for treatment, generally do well, and, consequently that there is great encouragement to try it;—the second, that, with regard to the lower extremities, the cases which reach the proper period for secondary amputations, may be accounted more successful than primary.

Only the best constitutions commonly reach the period of secondary amputation.

Of secondary amputations, it is but right to say, as has been observed by Alcock and others, that only the best constitutions survive, commonly speaking, to have them performed; and, as military authorities show, a large proportion of grave injuries, which are attempted to be saved, die under treatment.

In speaking of primary amputations, I have given several tables from civil hospitals, whose value is not impeached by any circumstance; but I regret to say, that with reference to secondary

The reports from civil hospitals, as regards secondary amputation for injuries, very defective; in military, greatly differing.

amputations, this is not equally the case. Professor Simpson's are of particular importance as regards primary; but from the circumstance of their showing no distinction between secondary amputations for injuries and for disease, that series is not applicable. The Glasgow tables, by Dr. Laurie and Dr. Steele, are exempt from this objection, but they are collected from the experience of a hospital whose local condition is such as to render the criterion an unfair one. I shall, however, give it, as by far the most extensive we possess in civil practice.

*Dr. Steele's Table.**

Secondary amputations for injury.		
	No.	*Died.*
Thigh	18	15
Leg	19	13
Arm	16	9
	53	37

Dr. Laurie's Table.†

Secondary amputations for injury.		
	No.	*Died.*
Thigh	24	16
Leg	5	3
Arm	14	7
	43	37

If we consider that these persons had been subjected to the avowedly tainted air of that hospital for a much longer period than the primary cases, we shall hardly wonder that the ratio of mortality has been so large. I may further add, that I do not see any distinction made between intermediate and secondary.

As regards military practice, the returns are much more copious than in civil; but, of the remarkable discrepancy in their results, arising, probably, from the same general circumstances which have been already adverted to, as regards primary amputations, the following brief statement may be admitted as sufficient proof. Of 255 secondary amputations of the lower extremities, performed between the 21st June and 24th December, 1813, in the Duke of Wellington's army, 149 died;‡ while, in Alcock's work, we find the following passage: "of gun-shot fractures of the leg, not complicated with injury of the joints, there were fifty-seven cases, of which twenty died; *eight underwent secondary amputation, and all recovered.*"§

* *Edinburgh Journal*, loc. cit. † Page 400. *Medical Gazette*, vol. xxvii.
‡ Guthrie, p. 41. § Alcock, p. 53.

If we investigate the causes of mortality in the table of secondary amputations I have given, we shall find that they materially differ from those which influence primary. Of the seven fatal cases, *none died from shock,* all from secondary processes; and if we proceed to examine the nature of the injuries which led to these amputations, we shall also find that they only include a part of those which lead to the performance of primary, and possess less of the character of *crush.* A reference to the detailed table at the end will show, that these secondary amputations were more especially for wounds of joints, hæmorrhage, or sphacelus from wounded arteries; thus, of the thirteen amputations of the thigh, six were occasioned by wounds of the knee joint, producing extensive suppuration; three from injured arteries, with hæmorrhage or sphacelus; and four only for compound fractures.

The analysis of my own tables shows that for the most part the causes were less connected with crush, and no case died from shock, all from secondary processes

I cannot conclude this part of my subject without adverting to a very important, but very doubtful question,—the nature of the injuries which require amputation, or, to take it in extenso, the propriety of amputating for injuries. It is well known that Bilguer, dissatisfied with the results of this practice, prohibited it in the Prussian army, and quite recently a surgeon of higheminence in France, Malgaigne, has again adopted the principle. This would not be a fitting occasion to go largely into details on this topic, but I may briefly say, that M. Malgaigne's opinions, previously doubtful on the subject, were finally determined by the facts stated, p. 73; and having adopted a different line of conduct, founded upon the principle of amputating in no case of injury, excepting when complicated with shattered wounds of hip or knee joints, he gives the result as follows:—Fractures of all limbs, 27; cured, 15; dead, 11; one suffered secondary amputation, and in great danger. His colleague, M. Gosselin, treated 25 cases on a similar plan, and had 16 successful. It may be difficult to meet this experience by any authenticated reports by individual surgeons. I find, however, in Mr. Alcock's valuable work, at p. 52, a table which partly meets the question, for out of 21 cases of gun-shot fractures of femur, while

The question of amtation for injuries.

M. Malgaigne's statements.

Mr. Alcock's and Dr. Laurie's.

six (it may be presumed the worst cases) underwent primary amputation, either on the field or in the hospital, 15 were reserved for cure, or secondary amputation; of these six were subsequently amputated. Of the primary amputations, five died; of the secondary, three; of the remaining twelve, eight died, and one remained without hope of recovery. These, too, were promising cases, "fine, healthy, young men," Mr. Alcock says, "to whom my attention was particularly devoted;" and it is not an improbable supposition that the greater proportion of these fifteen resulted from wounds by musketry, and not from cannon; but this is not stated. This may be taken as a strong counterpoise to the success above alluded to.*

Various ill-understood circumstances influence the results of all operations.

In endeavouring, then, to form any conclusion as to the results of operative surgery, we must take fully into account the remarkable variations which are produced by circumstances, often beyond our control, more often beyond our calculation. It is not only the experience of this, but of every other operation, shows it. Lithotomy, hernia, afford many examples of long runs of ill or good success in the hands of one or many surgeons. Local circumstances, peculiar conditions of air, of seasons, of the minds of men, all powerfully contribute to this uncertainty; but I must

* The records of civil practice are very meagre on this point, but to the valuable tables of amputation which Dr. Laurie has given, the following is added, shewing the "Results of compound fractures and dislocations not amputated," p. 401, *Medical Gazette*, vol. xxvii:—

	No.		*Cured.*		*Died.*
"Thigh . . .	5	...	1	...	4
Leg	21	...	15	...	6
Foot and Ankle	5	...	2	...	3
Arm	5	...	3	...	2
Elbow . . .	2	...	1	...	1
Fore-arm . .	2	...	1	...	1
	40	...	23	...	17"

Without, however, more definite information of the cause of injury, and classification as to its nature and extent, I hardly think we are warranted in drawing any certain conclusion from this; and, it must further be remarked, that the same causes which acted unfavourably in the case of amputations, must also in these cases.

differ from Mr. Alcock, who says, (contrasting the results of military and civil experience), "In large civil hospitals more leisure is attainable, but the nature of the injuries is not sufficiently various, and probably no one life would be long enough to register the requisite number," p. 67. For the latter remark, I feel that there is but too much foundation; but my own experience would teach me, that while military practice is limited as to the age of the patients (the prime of life) and the nature of the injuries, civil hospitals have the advantage of embracing every variety, and every age and condition of constitution, and from the very circumstance of their records being expanded over a long series of years, the favourable or unfavourable influence of particular cycles, or especial circumstances, will be merged in the lengthened observation. It can hardly be better shown that I have not over-stated the influence of such causes, than by a reference to Mr. Alcock's own experience. "In the first sixteen amputations performed for gun-shot wounds, consisting of primary and secondary, including a shoulder joint case, the majority of the thigh and leg, I lost but one, and that was an all but hopeless case of secondary amputation of the thigh. In the next eight, I lost seven, and the one saved was a complicated case, requiring amputation at the shonlder joint." Note, p. 96.

The effects of these fluctuations likely to be corrected by the experience spread over a long period in civil hospitals.

Instances of remarkably opposite results in military practice.

I think it necessary here to mention, as connected with the subject of amputation, a very important statement, which I find made by M. Malgaigne, with reference to the effects of treatment, which not only in itself is most important, but also as elucidating the state of depression and disorganization of the blood and general system, after severe injuries. This statement is neither more nor less than the results of treatment of the various soldiers wounded in the engagements which took place at Paris in 1814. I extract the statement from the *Medical Gazette*, Sept. 15th, 1848; it is as follows:—"A document emanating from the administration of the hospitals at Paris, which, it is much to be regretted, has not been published, throws much light on this question, *i.e.*, the deplorable results of a severe diet and emissions of blood. It is

M. Malgaigne's statement as regards the influence of treatment.

the tables of mortality among the different nations received into the different hospitals of Paris."

"In this table figure French, Prussians, Austrians, and Russians. The wounded of the first class were submitted to a severe system of diet; the Russians, on the contrary, were rarely submitted to a single *bouillon,* or more rarely to low diet; the less severely wounded had a full diet, and the rest middle diet, and, in addition, they had wine and brandy. The mortality was—

"French soldiers	-	-	1 in 7
Prussian ditto	-	-	1 in 9
Austrian ditto	-	-	1 in 11
Russian ditto	-	-	1 in 27

"This enormous difference is sufficiently eloquent."

It may be presumed that this report, sanctioned by the authority of M. Malgaigne, affords sufficient ground for reasoning upon. If so, it is highly important. It tends very strongly to show that the adoption of lowering methods, the anti-phlogistic plan, as it has been long termed, is not, at all events, the most successful in combatting the inflammations which ensue on injuries, with depressed powers and impaired organization, which, in many cases, are *the* permanent source of danger, and we might as well lower in cases of poison. The rational plan is to treat cases according to their nature and causes, and not to be governed by names. The variety of inflammations is very great, so ought to be the treatment; and on this I have ventured long ago to express my opinion, as also that many tonic and stimulating remedies are really "anti-inflammatory."* The record quoted above strongly confirms this view.

Bears strongly on the question of the nature of the inflammation consequent on these injuries.

There are many other circumstances which materially affect the results of amputations, but which are rather referrable to the mode of performing the operation, and the subsequent treatment, than to general circumstances affecting the whole question. Such, for instance, are the amputations by flap or otherwise, the closure of the wound, the employment of anæsthetic agents, &c.; but as these are, to a great extent,

The mode of operating and treatment of the stump, and other collateral causes affecting the question, may be reserved.

* "On the General Principles, and Nature, and Treatment of Inflammation," p. 186.

applicable to amputations for disease also; and as I may, perhaps, at a future period submit such observations as I may be enabled to make upon that series, I shall not proceed with this branch of the enquiry at present.

SUMMARY IN CONCLUSION.

It may now be permitted me to sum up, in conclusion, the more important points discussed in this paper.

Amputations for injuries are far more fatal than for disease, notwithstanding the subjects are commonly persons in the prime of life and health. The causes are, I believe, to be sought chiefly in the *nature of the injury*, which appears to have a material influence on the result, even when the injured part is completely severed from the body by amputation.

The description of injury which is attended with the most fatal consequences, is that which involves the greatest degree of *crush* or laceration, and this more especially in the lower extremities, partly from the larger mass disorganized, partly from the greater inability of the system to repair the injury, and the consciousness of this inability.

The effects which are produced by such injuries on the system, called shock, as is commonly known, often cause immediate or speedy death; but the impression produced on the system *does not pass away, even if the injured part is completely removed* and the patient survives; and the result is often a series of morbid processes, constituting destructive inflammation in the stump, and in various parts of the body, accompanied with a corresponding febrile disturbance. In these cases we see the *remote* effects of shock; in cases of speedy death, the *immediate*.

If the powers of the constitution are sufficient to overcome these morbid processes, either the patient recovers or is restored to a condition in which amputation may be performed with a fair prospect of success; but if it be performed from any urgent necessity before this period, it is much more frequently fatal. These are intermediate amputations.

The remarkable change wrought in the general system by such injuries is, then, very probably the cause of the great mortality of these amputations, as compared with those for disease. The

functions of every separate system are, doubtless, impaired thereby, but it is also probable that *the blood* undergoes the *more lasting* change, and consequently has the *strongest* influence on the result.

Many other circumstances also influence the result. Such are,—

The age, sex, and more or less healthy state of the patient;

The locality, season, and condition of the atmosphere, and various other extrinsic circumstances;

The more or less complete removal of every injured part;

The mode of operating, and especially the subsequent care; but as these apply in great measure (except as regards the third) to amputations for disease, as well as for injury, they cannot be taken into account in a *comparison* of the two.

The records of civil and military surgery both agree in the great amount of mortality after primary amputations, especially of the thigh; but while the former agree also remarkably as to the proportions, the latter exhibit very great differences, which, it is submitted, may be explained, partly by the ever-varying conditions which attend military practice; partly, by the wounds received in some engagements being inflicted by weapons which produce less or more extensive amount of crush or laceration, as musket balls, on the one hand, cannon shot on the other.

The apparent excess of mortality in civil hospitals, as compared with that in many instances of military practice, admit of explanation, upon the principle that the causes are more frequently of a nature resembling in their effects the latter or severer class.

The great discrepancy which appears in the records of both civil and military hospitals, as to the results of secondary amputations (of which, however, the latter alone offer a large number), may probably be explained, partly, by the unfavourable circumstances in which the subjects of secondary amputation are often placed in military practice; partly, by want of accuracy in distinguishing in these returns the intermediate in contradistinction to true secondary amputations; and it may be considered, that when the subjects of secondary amputations have been exempted from the influence of tainted air, and are submitted to the operation at the *true* period, the results are more favourable than those of primary, while the intermediate are the most fatal of the three.

The circumstances, then, which occasion the respective mortality of different classes of amputation depend less upon the *operation itself* than upon the changes resulting from the injury; and I may hereafter be able to show that amputations for disease are little fatal, if the operation be well performed, and the treatment be suitable.

I may further remark, that a position which has long obtained credit with the profession, namely, that amputation in the two upper thirds of the thigh are, *per se*, more fatal in a great degree than those in the lower, is doubtful. The fact is so, but the cause may be that (in addition to a larger extent of injury), these amputations are accompanied with the disadvantage of being performed through *injured parts*.

The very important and long-agitated question of the greater or less success to be expected from immediate or deferred amputation, in cases of injury, does not at present rest upon sufficient data to enable us to reason fairly upon it, but in the absence of sufficient authentic records, the opinion of a great number of eminent surgeons must be admitted as sufficient authority for preferring the former; and if, in such cases, it be allowable to reason, *a priori*, we should be led to conclude that the sympathetic influence of the comparatively small and well-conditioned surface of a stump, would be less likely to affect the already damaged system adversely, than the mangled mass otherwise left, which can only be retrieved by processes difficult, destructive, and often impossible.

Various methods of operating and of after (local) treatment, considerably influence the results; but, connected with this point, there is one which, from the recent evidence of a great French surgeon, appears of paramount importance,—it is the constitutional treatment of such injuries, a subject which demands the closest observation. It would appear that the system hitherto pursued, most generally, is adverse to recovery.

Facts, carefully observed, recorded, and analyzed, ought to lead to some useful results. Those which bear upon the subject of amputation are now both numerous and valuable. In endeavouring by a careful comparison of those which have fallen under my own observation, with the far more extensive series which, of late years,

have been laid before the public by others, to reduce them to some definite conclusions, I may, perhaps, have assisted in throwing light on the laws which govern this important, but very intricate subject. When, however, I consider that the attention of the most eminent masters of our art has been deeply engrossed in its consideration for more than a century, it becomes me to speak with the utmost diffidence of this attempt to reduce it to some fixed principles. I shall be amply rewarded for my trouble, if it shall be considered that I have in any degree forwarded the great object in view.

TABLE I.—PRIMARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
58, Case Book, vol. iv., p. 500.	Stout man.	Thigh crushed by waggon; knee-joint opened.	Shortly after he was brought in, on the bed, as he lay. 1826, April 7th.	J.	Recovered.	
67, Case Book, vol. iv., p. 564.	Stout man.	Both legs shattered, by the explosion of a mine.	Not sufficiently recovered for the operation until the morning of the subsequent day. Amputation of one leg and one thigh. 1847, Nov. 24th.	W.	Died on the following day.	
135, Case Book, vol. v., p. 390.	Boy.	Bad compound fracture of the thigh, and otherwise much injured.	Time not specified. 1833, August 28th.	W.	Died in a few hours. He sunk partly from the general injury.	
172, Case Book, vol. vi., p. 428.	Stout man.	Crushed wound into the knee, with obliteration of popliteal artery and vein, by coagulum.	Shortly after. 1836, May 2nd.	J.	Died from phlebitis, which came on twenty days after the operation.	The vein was tied, but no inflammation found after death in that.
177, Case Book, vol. vi., p. 422.	Man.	Compound fracture of leg.	1836, August 8th.	Z.	Stump became sloughy, and sixteen days after the operation stated to be doing ill: probably died.	

TABLE I. (*Continued*).—PRIMARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
206, Case Book, vol. vii., p. 415.	Lad, 19.	Limb crushed by a thrashing machine.	1839, August 28th.	W.	Recovered.	
267, Case Book, vol. viii., p. 465.	Man, 49.	Knee-joint shattered by the bursting of a small cannon.	Very shortly after. 1846, June 26th.	J.	Recovered.	
277, Case Book, vol. ix., p. 312.	Boy, 13.	Crush of thigh and leg from thrashing machine.	In a few hours. 1846, December 4th.	X.	Survived about a week, and died from irritative fever.	
278, Case Book, vol. ix., p. 315.	Man, 50; feeble.	Leg crushed by a block of stone.	Performed under increasing collapse, which could not be arrested. 1846, December 18th.	J.	Died in half-an-hour.	
287, Case Book, vol. ix., p. 339.	Man, 50.	Laceration of lower part of thigh, extending into the knee-joint.	About four hours after his admission. 1848, January 8th.	Z.	Recovered.	

Thigh.—Ten primary; four recovered, six died; of these, three sunk shortly after the operation, three of irritative fever and the consequences, or phlebitis.

TABLE I. (*Continued*).—THIGH. EARLY INTERMEDIATE AMPUTATIONS.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
150, Case Book, vol. vi., p. 400.	Healthy man, aged 68.	Crushed leg.	Four days afterwards. 1834, May 31st.	J.	Amputation performed during spreading inflammation, but through sound parts. He sunk and died the day after.	In this case, sphacelus was imminent, and the operation was performed on the grounds urged by Larrey, and prior to the spreading inflammation attacking the thigh.
154, Case Book, vol. iv., p. 405.	Stout elderly man.	Crushed leg.	Two days afterwards, a spot of sphacelus appearing. 1834, June 20.	Z.	Died eighteen days afterwards. Stump sloughy.	
38, Case Book, vol. iv., p. 451.	Man, 55.	Rupture of the femoral artery, from the crush of a waggon, and producing sphacelus of the foot and leg.	Twelve days afterwards. October 18th, 1822.	J.	Recovered.	
Three intermediate; two died, one recovered.						

Note.—The most important feature in such tables, beyond all doubt, is the record of the results, and in these the results in several cases are not appended; it is, therefore, important that I should state upon what grounds I assume that the cases terminated fatally or otherwise where such an omission occurs. From two causes the deaths after operations could seldom escape my notice, first, because these patients are placed in small separate wards, which I have been in the constant habit of visiting whenever I went round, and it could rarely happen that a death occurred without my knowing it; and, again, I was Curator of the Museum during the whole period, and I felt it more particularly my duty to attend the examination of those who died, when permission to examine could be procured. When a death, then, occurred, it could scarcely escape my notice, and I think it rarely happened that I did not record the fact, especially in such cases as these.

Some cases may have terminated fatally after their removal from the operation wards without my knowing it, yet, as it has been the general practice to allow them to remain in those wards until out of danger, if a patient died subsequently, the result in few cases could be fairly ascribed to the operation. In assuming, therefore, that when no death has been recorded as a consequence of operation, it is not likely to have occurred, I have not greatly erred, in all probability, but it will be found that I have not engaged in any chain of reasoning founded upon *perfect* accuracy; neither my own, nor, as I believe, any other tables yet given, afford such an opportunity.

It is right to add, that in these tables *there is no selection of cases.* I might have contented myself with giving only those which were complete, but the omission of a single case, however imperfectly noted, would have vitiated the whole report. As it is, I have given them in regular order, numbered from the beginning to the completion of 300 cases, referring to the volume, page, subject, accident, limb, operator, and result, when known. Had these points been completely followed out in all instances, little more would have been required. Under the head "Surgeon," my own initial is preserved; the others are arbitrarily adopted, but in every instance are noted in my Case Books under the real name.

TABLE II.—PRIMARY AMPUTATIONS. LEG, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Amputation.*	*Surgeon.*	*Result.*	*Remarks.*
92, Case Book, vol. v., p. 338.	Lad, 17.	Fracture, with laceration.	November 5th, 1849.	Y.	Died.	Tetanus eleventh day.
137, Case Book, vol. v., p. 391.	Stout man.	Crushed foot.	September 8th, 1833.	Z.		
146, Case Book, vol. v., p. 398.	Man, 50.	Laceration and compound fracture from loaded waggon.	April 10th, 1834.	Y.	Died fifteenth day, from spreading inflammation and sphacelus.	
155, Case Book, vol. vi., p. 408.	Healthy young man.	Compound fracture from loaded waggon.	July 22nd, 1834.	W.		
178, Case Book, vol. vi., p. 432.	Man, 70.	Crushed leg by waggon.	August 13th, 1836.	J.	Recovered.	
194, Case Book, vol. vii., p. 408.	Woman, 32.	Compound luxation of ancle, with much fracture and crush, from the wheel of a loaded caravan.	October, 1838.	J.	Recovered.	Six months' pregnant at the time.
200, Case Book, vol. vii., p. 413.	Man, 60.	Compound fracture.	April 21st, 1839.	Y.	Died, April 26th.	This man was paralytic before the accident.

TABLE II. (*Continued*).—PRIMARY AMPUTATIONS. LEG, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
232, Case Book, vol. viii., p. 401.	Man.	Compound fracture.	August 31st, 1848.	Z.	Recovered, October 29th.	
239, Case Book, vol. viii., p. 414.	Boy, 13.	Leg crushed in a flour mill.	May 26th, 1843.	X.	Died four hours after.	
252, Case Book, vol. viii., p. 447.	A. B.	Leg.	February 7th, 1845.	Z.		
260, Case Book, vol. viii., p. 459.	Lad, 19.	Compound fracture, with laceration. The foot mashed in a thrashing machine.	January 5th, 1846.	J.	Recovered, Feb. 14th.	
272, Case Book, vol. ix., p. 306.	Young stout navigator.	Both legs crushed, and both amputated.	November 2nd, 1847.	V.	Died in thirty-six hours.	Collapse increased before amputation, in spite of every exertion. After it he lived 36 hours.
285, Case Book, vol. ix., p. 330.	Man, 56. Unhealthy, with varicose veins.	Compound fracture, produced by jumping off a loaded waggon.	August 2nd, 1847.	J.	Death from tetanus, which came on the 15th day.	
291, Case Book, vol. ix., p. 347.	Lad, 16.	Foot crushed by a railway engine.	May 24th, 1848.	X.	Recovered.	

TABLE II. (*Continued*).—PRIMARY AMPUTATIONS. LEG, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
293, Case Book, vol. ix., p. 353.	Man, 52.	Laceration of foot from a quarry explosion.	August 3rd, 1848.	V.	Recovered.	The collapse continued 36 hours after the operation, but he was saved by great assiduity.
298, Case Book, vol. ix., p. 365.	Boy. 10.	Leg crushed in a paper mill.	December 5th, 1848.	X.	Recovered, Jan. 27, 1848.	
Leg.—Primary, sixteen. Six died; seven recoveries entered; three believed to have recovered. Of the six who died, two were from tetanus, two from collapse, and two from irritative fever and consequences.						

TABLE III.—PRIMARY AMPUTATIONS. ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
13, Case Book, vol. ii., p. 505.	Young man.	Laceration and crush of the whole arm and shoulder-joint.	1819, June 27th. Shortly after the accident. No symptoms of shock. At the shoulder-joint.	J.	Recovered.	
24, Case Book, vol. iii., p. 498.	Woman, 56.	Lacerated wound of arm (and fore-arm of other side) in a bark mill.	1820, March 25th. Six hours after the accident. Double operation.	Y.	Recovered.	

TABLE III. (*Continued*).—PRIMARY AMPUTATIONS. ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
77, Case Book, vol. v., p. 309.		For injury.	1828, September 8th.	Y.		
111, Case Book, vol. v., p. 361.	Young man.	Compound fracture, and injury of shoulder-joint, in a grist mill.	1832, Feb. 10th. At the shoulder-joint.	W.	Recovered.	
115, Case Book, vol. v., p. 365.	Lad, 16.	Arm and fore-arm crushed in a mill.	1822, May 17th.	Y.		
117, Case Book, vol. v., p. 368.		Compound fracture.	1832, July 27th.	W.		
123, Case Book, vol. v., p. 381.		Lacerated arm.	1833, January.	W.		
125, Case Book, vol. v., p. 382.	Girl.	Compound fracture.	1832, December.	W.		
143, Case Book, vol. v., p. 397.		Laceration.	1833, December 14th.	W.		
144, Case Book, vol. v., p. 397.		Laceration.	1834, March 18th.	Y.		

TABLE III. (*Continued*).—PRIMARY AMPUTATIONS. ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
153, Case Book, vol. vi., p. 405.	Middle-aged man.	Arm lacerated in a bark mill.	1834, June 19th.	J.	Recovered.	It was followed by a very severe attack of diffuse inflammation, and his recovery was long and difficult.
164, Case Book, vol. vi., p. 418.	Boy, 14.	Arm crushed in a grist mill.	1835, August 22nd.	W.	Died within an hour, from collapse.	
179, Case Book, vol. vi., p. 439.	Old man.	Arm crushed in a bark mill.	1837, January 28th.	J.	Died March 20th.	Secondary inflammation and suppuration ensued, and increased during an influenza. He struggled on till the date specified.
181, Case Book, vol. vi., p. 443.		Laceration.	1837, August 2nd.	Y.		
246, Case Book, vol. viii., p. 434.		Laceration.	1843, February.	X.	Recovered.	
257, Case Book, vol. viii., p. 450.	Stout man.	Laceration, with wound of brachial artery and elbow-joint.	1844, June 2nd.	Z.	Recovered.	

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
264, Case Book, vol. viii., p. 459.	Fine young man.	Severe compound fracture near the shoulder.	1847, February 13th.	J.	Died.	Partly from shock, he having also a comminuted fracture of the other thigh and a lacerated wound of the foot on the same side, which was attacked with diffuse inflammation. He lived ten days.
284, Case Book, vol. ix., p. 323.	Boy, 4.	Arm crushed by waggon.	1847, June 16.	J.	Recovered.	He had great collapse in the first place, and, afterwards, bronchitis and irritative fever, which reduced him much.
299,	Man, 21.	Lacerated and crushed arm, at shoulder-joint.	1849, April 30.	J.	Recovered,	During the collapse which followed the operation an enema with brandy and milk was employed with great benefit.

Arm, 19.—Three died, one from collapse, two secondarily; but in one of these (No. 264) there was extreme injury of other parts. Eight are entered as recovered; of the other eight I have no entries as to the result, but I assume that they recovered, as there is nothing entered to render it probable they did not. It may here be repeated, that I entered operations of every kind in my Case Book as they occurred, with the view that if anything more than usual followed I might make notes accordingly. I assume, therefore, that when no such entries are subsequently made (with few exceptions), these and all other operations were attended with no unusual circumstances. Amputations of the arm were so commonly successful that, generally speaking, I attended less to the details than in the lower extremity.

TABLE IV.—PRIMARY AMPUTATIONS. FORE-ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
12, Case Book, vol. ii., p. 501.	Man, 20.	Gun-shot wound.	1819, January 24th. 3 p.m. Operation at six.	J.	Recovered.	Had irritative fever.
40, Case Book, vol. iv., p. 456.	Boy.	Gun-shot wound.	1822, January 7th.	J.	Recovered.	
41, Case Book, vol. iv., p. 456.	Man.	Gun-shot wound.	1822, January.	J.	Recovered.	
42, Case Book, vol. iv., p. 456.	Man.	Gun-shot wound.	1822, January.	J.	Recovered.	
109, Case Book, vol. v., p. 360.	Man.	Gun-shot wound.	1831, November 5th.	Z.		
147, Case Book, vol. v., p. 399.	Woman.	Lacerated hand.	1834, April 16th.	Z.		

TABLE IV. (*Continued*).—PRIMARY AMPUTATIONS. FORE-ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
157, Case Book, vol. vi., p. 401.	Girl, 17.	Hand crushed between the rollers of a paper mill.	1834, September.	J.	Recovered, October 10th.	
183, Case Book, vol. vi., p. 444.	Lad, 20.	Shattered hand in grist mill.	1837, October 8th.	J.	Recovered.	Had enteritis.
197, Case Book, vol. vii., p. 411.	Man, 54.	Shattered hand in mill.	1839, February 22nd.	J.	Recovered.	
211, Case Book, vol. vii., p. 418.	Man.	Gun-shot wound.	1839, November 10th.	Z.	Recovered.	
231, Case Book, vol. viii., p. 400.	Man, 40.	Laceration in a thrashing machine.	1842, June 20th.	W.	July 2nd, doing well.	Erysipelatous inflammation, but doing well a fortnight afterwards.
247, Case Book, vol. viii., p. 436.	Boy, 8.	Laceration in a bark mill.	1844, May.	X.	Recovered.	

TABLE IV. (*Continued*).—PRIMARY AMPUTATIONS. FORE-ARM, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
249, Case Book, vol. viii., p. 437.	Boy.		1844, June 20th.	X.		
251, Case Book, vol. viii., p. 446.	Boy.	Laceration.	1845, January.	Z.		
261, Case Book, vol. viii., p. 459.	Boy, 11.	Laceration in cider mill.	1846, January 21st.	J.	Recovered.	
275, Case Book, vol. ix., p. 307.	Lad, 18.	Gun-shot wound.	1846, November 14th.	R.	Recovered.	
286, Case Book, vol. ix., p. 332.	Middle-aged man.	Laceration in thrashing machine.	1847, October 5th.	V.	Recovered.	
299, Case Book, vol. ix., p. 367.	Young man, 20.	Lacerated hand from bursting of a gun.	1849, January 23rd.	V.	Recovered.	

Fore-arm, 18.—Of these, fourteen recoveries are entered, and of the remainder *I have no doubt*.

TABLE V.—SECONDARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
5, Case Book, vol. i., p. 290.	Stout man.	Compound fracture of thigh. Wound of knee-joint, May 4th, 1817, from falling from a tree on an axe.	1847, May 25th. The limb full of abscesses, and his state very bad.	Y.	Died, worn down by irritative fever, June 14th.	Had nearly sunk from collapse after the operation.
23, Case Book, vol. iii., p. 494.	Young man.	A ball lodged in the knee-joint at the battle of Waterloo was removed by a surgeon long afterwards, and gave rise to severe inflammation, and in about five weeks he was brought to the hospital in a very evil state of limb and health.	1820, March 14th, a few days after his admission.	J.	Improvement speedily followed the operation, but there was a considerable struggle. Was made an out-patient June 15th. Recovered.	
50, Case Book, vol. iv., p. 483.		Compound fracture, with sinuses extending above the knee.	1824, July.	Y.		
83, Case Book, vol. v., p. 312.	Young man.	Received a wound in the knee-joint from a hatchet, and was admitted on the third day. Abscesses formed, extending to the upper part of the thigh.	1829, March 26th.	W.		

TABLE V. (*Continued*).—SECONDARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
87, Case Book, vol. v., p. 331.	Man, 71.	Rode over, July 29, 1829. The horse stepped on his right leg, and he got a compound fracture at the upper part; extensive suppuration occurred, with irritative fever.	1829, August 29th.	J.	Was discharged in the month of October. Recovered.	
103, Case Book, vol. v., p. 352.	Man.	Wound of knee-joint, giving rise to extensive abscesses and much exhaustion.	1831, March.	W.	Died of secondary inflammation.	Amputation in middle third.
151, Case Book, vol. vi., p. 401.	Lad, 10.	Gun-shot wound, June 3, just below the knee; both the tibials and the popliteal nerve were wounded. Sphacelus of the limb occurred, with much constitutional irritation.	1834, June 8th.	W.	June 25th, going on very well. The stump *had* been sloughy and suppurated largely, and his constitution much disturbed.	
166, Case Book, vol. vi., p. 420.	Man.	Middle of Sept., 1835, wound of the knee-joint from the wheel of a cart. Extensive suppurations of the leg and thigh, and great exhaustion.	1835, October 3rd, about three weeks after the accident, on the bed as he lay.	J.	The last entry is Oct. 10, when his state was very doubtful, but, from recollection, I think he recovered.	

TABLE V. (*Continued.*)—SECONDARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
173, Case Book, vol. vi., p. 429.	Man.	Admitted May 21, 1836, about eight or ten days after the accident, which was a laceration of the popliteal artery, without external wound, from the wheel of a large waggon, causing sphacelus of the limb; a line of demarcation formed.	1836, May 28th.	Z.	From the state described of impending dissolution, on July 16th, most probably this case terminated fatally.	
174, Case Book, vol, vi., p. 430.	Healthy country man.	Admitted in consequence of a wound of the knee-joint by a hook, about two months before. Extensive suppurations and high irritative fever when he came in. After endeavouring to improve his state in vain, amputation performed.	1836, July 7th.	J.	Died, exhausted, the end of the month.	
176, Case Book, vol. vi., p. 432.	Man.	Compound fracture; the limb in a very bad state, and the operation necessarily high up.	1836, July 28th. Flap high up.	Y.	Recovered.	
182, Case Book, vol. vi., p. 432.	Lad.	Compound fracture of the leg, followed by extensive suppuration and sphacelus of the integuments.	1837, September 18th.	Y.	October. I believe he did well.	

TABLE V. (*Continued*).—SECONDARY AMPUTATIONS. THIGH, IN DETAIL.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
215, Case Book, vol. vi., p. 444.	Healthy man.	Was a case of fractured patella; the joint in a state of suppuration; the upper portion retracted four inches. The suppuration extended high up the thigh. He came in several weeks after the accident.	1840, June 17th.	Y.	Case, I think, did well.	
218, Case Book, vol. vii., p. 428.	Young man.	Compound fracture of leg; extensive suppuration and grave constitutional symptoms; was in a very bad state at the time of the operation.	1840, December 6th.	W.	Early in January the case is entered as doing badly.	
276, Case Book, vol. ix., p. 308.	Man, 40.	Compound fracture of the right leg from fall from scaffold, with other injuries; at the expiration of five weeks there was hæmorrhage, which recurred, and operation performed.	1840, November 20th.	X.	Recovered.	

Thigh, 15.—Three deaths entered; two probably died (173 and 218). Four recoveries entered; four probably did well (166, 176, 182, and 215); two (50 and 83) are very doubtful.

These cases of secondary amputation often sink, after a considerable interval, and when removed to their own wards. I am, therefore, more doubtful about those which are not entered as having died or recovered than about any others, as from this cause I am more likely to be ignorant of the termination. Assuming that the account is correct as to 13, it would give five deaths and eight recoveries; but, then, the nature of the accident is different for the most part from those which gave rise to primary amputations, which were chiefly cases of severe crush or laceration, with fracture. Of the secondary, six originated from wounds of the knee-joint, three from injured arteries, with sphacelus or hæmorrhage, and four only were cases of compound fracture. Of the latter only one, in all probability, died (218). Some of these cases [illegible] of late intermediate amputations, as I have elsewhere remarked, such especially are Nos. 151 and 173, which

TABLE VI.—SECONDARY AMPUTATIONS. LEG, ARM, AND FORE-ARM, IN DETAIL.

LEG.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
7, Case Book, vol. ii., p. 409.	Man.	Compound fracture. Crush.	1819, February 28th, about ten days after the accident.	Y.	In all probability recovered.	
45, Case Book, vol. iv., p. 474.	Woman, 85.	Compound fracture, from fall from a donkey.	1824, February 8th.	W.	Recovered.	
190, Case Book, vol. vii., p. 405.	Man, 40.	Compound luxation of foot.	1838, March 30th, about a month after the accident.	J.	Recovered.	
207, Case Book, vol. vii., p. 416.	Man, 54.	Compound fracture.	1839, September 13th, about three weeks after the accident; the man in a very bad state at the time of the operation.	Y.	Died, October 10th.	
265, Case Book, vol. viii., p. 460.	Young man.	Injury of the ancle, producing extensive suppuration.	1846, March 4th, a very considerable time after the injury.	J.	Recovered.	

Five cases.—Three entered recovered; one, in all probability, died. The number, as compared with the thigh, is small; the number of recoveries, in proportion, large; the only fatal case, a very unfavourable one. All these accidents occurred at a remote part of the lower extremity.

TABLE VI. (*Continued*).—SECONDARY AMPUTATIONS. LEG, ARM, AND FORE-ARM, IN DETAIL.

ARM.

No.	*Subject.*	*Accident.*	*Period of Operation.*	*Surgeon.*	*Result.*	*Remarks.*
16, Case Book, vol. ii., p. 522.	Young man.	Sphacelus, from scald.	1819, August 3rd.	J.	Recovered.	
81, Case Book, vol. v., p 314.	Man, 69.	Lacerated hand, with extensive abscesses.	1820, November.	J.	Recovered.	
168, Case Book, vol. vi., p. 417.	Man.	Hand and arm lacerated by the run of a rope, and followed by traumatic gangrene.	1836, February, being about ten days after the accident.	Z.	Recovered.	
188, Case Book, vol. vii., p. 402.	Man.	Hand shattered by the bursting of a gun. Sphacelus ensued.	1838, January, rather more than a fortnight after.	Y.	Died.	The stump having mortified.
Four cases.—Three recovered, one died, namely, a case where amputation was performed for traumatic sphacelus.						
FORE-ARM.						
186, Case Book, vol. vi., p. 446.		Hand crushed by a heavy roller.	1837, October 31st.	W.	Recovered.	
296, Case Book, vol. ix., p. 359.	Young man.	Laceration of hand, and subsequent hæmorrhage.	1848, October 8th.	X.	Recovered.	

Two cases, both recovered. The comparatively *small number of amputations* of the leg, arm, and fore-arm cannot fail to be remarked; and this must be fully taken into account in estimating the relative mortality shown in table, p. 75, which *otherwise* might appear to show a larger proportion in secondary amputations.

A CASE OF THE

HIGH OPERATION OF LITHOTOMY.

BY GEORGE MURRAY HUMPHRY, ESQ.,

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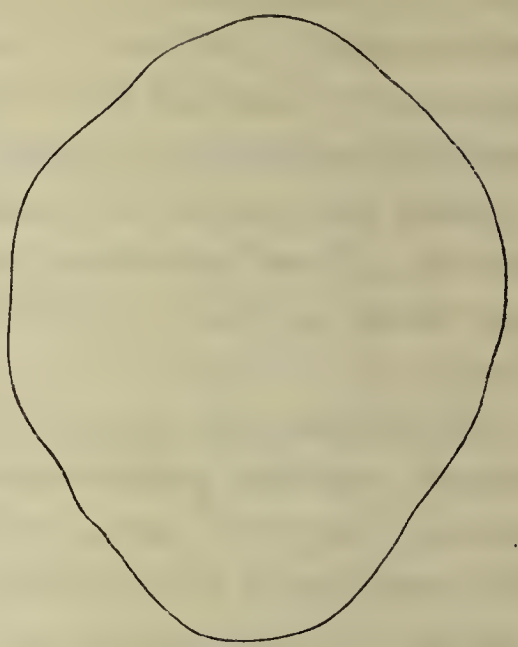
Thomas Sutton, aged 14, from Chatteris, was admitted into Addenbrooke's Hospital on September 28th, 1848; a light-complexioned lad, of delicate appearance and quiet manner, very slow and cautious in his movements. He suffered the usual symptoms of stone in the bladder, with constant stillicidium, except when he prevented the passage of urine by holding the penis, which he was in the habit of doing, because it afforded him some relief from pain. His parents said that he had been troubled in this way for seven years, but that from birth he had never been able to hold his water or to pass it so well as other children. During the last few months his sufferings had increased very greatly. The sound came in contact with a stone immediately on entering the bladder, and could be passed only a short distance beyond the prostate on account of the size of the stone. The finger passed in the rectum found the bladder distended with a large calculus, of oval shape, which seemed to fill up the fore part of the pelvis; there appeared to be only one stone, and no great inequalities could be felt on its surface.

My colleagues, Mr. Lestourgeon and Mr. Hammond, agreed with me that the stone was of too large size to admit of its being extracted entire by the lateral or bi-lateral incisions. Accordingly after much deliberation and investigation of the results of different modes of proceeding in cases of this sort, we decided in favour of the high operation, thinking that, with all its dangers and difficulties, it was to be preferred to extensive lateral incisions, with the necessity of breaking up the stone and extracting it piece-meal; to the recto-vesical operation, or to the plan proposed by Sir B. Brodie, of carrying the lateral incision into the rectum. Accordingly, on the 20th of October, I performed the operation above the pubes. The lad was placed on his back, with his shoulders a little raised and his legs hanging over the end of the table. A catheter having been introduced into the bladder to draw off any urine that might have accumulated there, an incision was made over the linea alba, from about midway between the umbilicus and the pubes to the root of the penis, care being taken to avoid the vessels running upon the dorsum of the penis. The linea alba was soon exposed and divided on a director, nearly to the same extent as the integuments. The recti-muscles were cut through at their attachment to the pubes, and transverse incisions were carried to some little distance beyond them, so as to afford sufficient room. The fore-finger was then pushed behind the pubes, and the knife used under its guidance to divide the cellular and adipose tissues in front of the bladder, while the exposed peritoneum was held back and protected by the other fingers. In this way the bladder was slowly reached, its distance from the surface being considerable. The stone could be felt through it; and, placing one fore-finger in the rectum and the other in the wound, I could poise the stone between them, and ascertained that there was no urine in the bladder. The point of the knife was now pressed through the coats of the bladder upon the stone, and as soon as the opening so made was enlarged a considerable quantity of urine escaped, filling up the wound and running over the sides of the body, in spite of the sponges and syringes with which we were provided in case of such an emergency. It was necessary to enlarge the opening into the bladder several times with a blunt-pointed bistoury, and this was done both in lateral directions and towards the prostate. The coats of the bladder were thick, and embraced the stone so closely

that it was sometime before I could introduce the end of my finger into its cavity. At length I succeeded in doing so, and dislodged the stone from its bed by turning up one end of it. It was then soon grasped with the forceps introduced carefully so as to avoid injuring the coats of the bladder, and its extraction was easily effected. Urine continued to escape in great quantities during the whole of these proceedings which occupied considerable time.

The bladder was syringed two or three times with warm water, to wash away some gritty matter that remained in it. A gum-elastic catheter was then passed by the urethra and brought out into the wound, and a small skein of lamp-cotton was secured to it and pulled through the urethra as the catheter was withdrawn, one end of it being left projecting into the bladder; attached to this end was a capillary syphon, made of lamp-cotton, enclosed in a tube of oil-silk, and extending in a tuft-like manner beyond the extremity of the tube. This tuft was introduced into the bladder, and kept fixed at its lower part by means of the skein drawn through the urethra, while the other end of the syphon hung down two feet over the side of the bed. The wound was closed by stitches in its two upper thirds, to prevent the protusion of the peritoneum.

With the exception of the rapidity of the pulse, which for three or four days was above 140, he suffered no unfavourable symptom. The urine flowed copiously into the wound, beside the syphon, as well as through the latter; and as the syphon was, therefore, not effectual in emptying the bladder and preventing the escape of urine into the wound, I removed it, together with the urethral skein, on the second day. On the third day the bowels acted freely, after a dose of castor oil, and the pulse began to fall. Some small sloughs of cellular tissue came away through the wound, which afterwards granulated and healed up, so that by the end of November he had left his bed, and the urine passed entirely by the natural channel. His convalescence was for a time impeded by feverish symptoms, followed by the discharge of some crumbling mortar-like masses through the wound. When these had passed away he quickly regained his health and strength; and I learnt, a few weeks ago, that he was quite well, and at work in the fields.



The stone was of the size represented, nearly egg-shaped. It weighed rather more than an ounce and a half, its large comparative size being due to the loose friable structure of its outer layers. It had evidently filled and been closely embraced by the bladder. I must confess that I expected to have found it larger, and that I was deceived, together with all the several surgeons who examined him, by the impression given to the finger in the rectum. I suppose the thickened coats of the bladder, tightly grasping the stone, gave us the idea that the latter was so much larger than it really was. However, its size was sufficient to have occasioned very great difficulty in the lateral operation in so young a subject.

The feeling of surgeons, in this country more particularly, has been of late years very adverse to the high operation of lithotomy; so much so, that I am not aware of its having been performed in England since the unsuccessful attempts which were made in St. George's Hospital, soon after the favourable cases published by Sir Everard Home. That the lateral operation deserves the preference in by far the majority of cases, and that the high operation is to be accepted only as an occasional and disagreeable alternative, I need not stop to prove. The only question is, whether it is to be resorted to under any circumstances, and the answer to such a question will be best afforded by the following table of cases, which I have collected from various quarters:—

LIST OF PATIENTS ON WHOM THE HIGH OPERATION OF LITHOTOMY HAS BEEN PERFORMED.

Operator.	*Age.*	*Weight.*	*Size of Stone.*	*Result.*	*Remarks.*
1. Collot	–	–	–	Cure.	
2. Pierre Franco ...	2	–	Size of hen's egg.	Cure.	Both these were after the lateral operation had failed.
3. A French Surgeon	–	–	–	Fatal.	
4. Home	16	℥j.	–	Cure.	
5. Ditto	40	–	–	Cure.	
6. Ewbank	–	–	–	Fatal.	Operation not finished.
7. Kirby	–	–	–	Cure.	Performed for removal of broken catheter.
8. Ballingall	6	–	Two inches diam.	Fatal.	Peritonitis.
9. Greenfield	–	–	–	Cure.	
10. Proby	20	–	–	Cure.	For removal of bodkin.
11. Douglas	17	–	–	Cure.	
12. Ditto	8	–	–	Cure.	
13. Ditto	3	–	–	Fatal.	Convulsions.
14. Ditto	14	–	–	Cure.	Peritoneum wounded. Intestines presented and replaced.
15. Cheselden	7	–	–	Cure.	
16. Ditto	14	–	–	Cure.	
17. Ditto	11	–	–	Cure.	
18. Ditto	12	–	–	Cure.	
19. Ditto	9	–	–	Cure.	
20. Ditto	18	–	–	Fatal.	Suppuration and stones in kidney.
21. Ditto	19	℥iij. ℥ij.	–	Cure.	
22. Ditto	11	–	–	Cure.	
23. Ditto	4	–	–	Cure.	
24. Ditto	A boy.	–	–	Cure.	
25. Pye	A boy.	–	–	Fatal.	On sixteenth day abscesses and sloughing about wound.
26. Ditto	5	–	–	Cure.	
27. Ditto	19	–	–	Fatal.	Ulcerated bladder.
28. Ditto	9	–	Large.	Fatal.	Suppuration of kidney.

LIST OF PATIENTS ON WHOM THE HIGH OPERATION OF LITHOTOMY HAS BEEN PERFORMED.

Operator.	*Age.*	*Weight.*	*Size of Stone.*	*Result.*	*Remarks.*
29. Thornhill	8	ʒiij.	–	Cure.	
30. Ditto	6	ʒv.	–	Cure.	
31. Ditto	15	ʒj.	–	Cure.	
32. Ditto	45	ʒiv.	–	Cure.	Died eight months after, of suppurated kidney.
33. Ditto	4	–	Size of peach stone.	Cure.	
34. Ditto	48	ʒiij. ʒj.	–	Cure.	
35. Ditto	14	ʒiv. ʒij.	–	Fatal.	Gangrened peritoneum.
36. Ditto	13	ʒj. ʒvj.	–	Fatal.	Peritoneum wounded.
37. Ditto	18	–	–	Cure.	
38. Ditto	5	ʒiiiss.	–	Cure.	
By ditto (5 cases)	–	–	–	4 Cures. 1 Fatal.	
44. Maigill	Old man.	2 stones, ʒivss. each.	–	Cure.	
45. Ditto	13	ʒij. ʒj.	–	Cure.	
46. Ditto	35	ʒv.	–	Fatal.	Stone not removed, being encysted.
47. Ditto	8	–	Size of nutmeg.	Cure.	
48. Heister	30	–	–	Fatal.	After unsuccessful attempt to remove stone by lateral operation.
49. Biernier	4	–	–	Cure.	
Paul (four cases)	–	–	–	2 Cures. 2 Fatal.	
54. Baseilhac	18	–	–	Cure.	
55. Deschamps ...	6	–	–	Cure.	
56. Dupuytren	62	ʒviss.	–	Cure.	
57. Blandin	15	ʒij.	–	Fatal.	Stone not removed by high operation—recto-vesical. Performed on same day. Peritonitis.
58. Lisfranc	–	ʒvij.	–	Cure.	
By ditto (2 cases)	–	–	–	Two Fatal.	Infiltration of urine.
61. Hutchinson ...	–	–	–	Cure.	
62. Roux	Old man.	–	–	Fatal.	Infiltration of urine.

LIST OF PATIENTS ON WHOM THE HIGH OPERATION OF LITHOTOMY HAS BEEN PERFORMED.

Operator.	*Age.*	*Weight.*	*Size of Stone.*	*Result.*	*Remarks.*
63. Amussat	67	–	–	Fatal.	Infiltration of urine.
64. Ditto	78	–	Six stones.	Cure.	
65. Matthieu	–	–	–	Cure.	
66. Baudeus	23	–	–	Cure.	
67. Souberbielle ...	70	Between ʒiii. & ʒiv.	300 stones.	Fatal.	Inflammation of brain and kidneys.
68. Ditto	70	–	Size of nut.	Fatal.	Peritonitis. Infiltration of urine.
69. Ditto	72	–	Size of nut.	Cure.	
70. Ditto	80	ʒij.	–	Cure.	Stone adherent.
71. Ditto	66	ʒiv. ʒvj.	–	Cure.	
72. Ditto	63	ʒvj.	–	Fatal	Peritonitis. Iliac abscess.
73. Ditto	18	ʒj.	–	Cure.	
74. Ditto	52	ʒiij. ʒvj.	–	Cure.	
75. Ditto	21	–	Size of nut.	Fatal.	Peritonitis.
76. Ditto	75	ʒv.	–	Fatal.	Laryngitis.
77. Ditto	73	ʒij.	–	Fatal.	
78. Ditto	70	ʒiv.	Two stones.	Cure.	
79. Ditto	54	ʒiv.	–	Fatal.	Peritoneum wounded. Peritonitis. Diseased kidneys.
80. Ditto	65	ʒiij.	–	Fatal.	
81. Ditto	58	–	–	Fatal.	Hæmorrhage. Source of blood not clear.
81. Ditto	59	–	–	Cure.	
82. Ditto	5	–	Size of olive.	Cure.	
83. Ditto	76	ʒiij.	–	Cure.	
84. Ditto	72	ʒiv.	–	Fatal.	
85. Ditto	60	–	Three stones.	Cure.	
86. Ditto	70	–	Size of egg.	Cure.	
87. Ditto	67	–	Twelve stones.	Cure.	
88. Ditto	78	ʒiss.	Two stones.	Cure.	

LIST OF PATIENTS ON WHOM THE HIGH OPERATION OF LITHOTOMY HAS BEEN PERFORMED.

Operator.	*Age.*	*Weight.*	*Size of Stone.*	*Result.*	*Remarks.*
89. Souberbielle ...	64	℥ij.	–	Cure.	
90. Ditto	62	℥ij.	–	Cure.	
91. Ditto	64	℥j. ʒij.	–	Cure.	
92. Ditto	69	℥ij. ʒss.	–	Cure.	
93. Ditto	80	–	Two stones.	Cure.	
94. Ditto	74	–	Five stones.	Fatal.	Abscess between bladder and rectum.
95. Ditto	65	℥vij. ʒiiss.	–	Cure.	
96. Ditto	70	–	Four stones.	Cure.	
97. Ditto	54	–	Two stones.	Cure.	
98. Ditto	70	℥ij. ʒiij.	–	Cure.	
99. Ditto	65	℥v. ʒj.	–	Cure.	
100. Ditto	75	–	Four stones.	Cure.	
101. Ditto	65	℥iiss.	–	Cure.	
102. Ditto	77	–	–	Cure.	
103. Ditto	68	–	Three stones.	Cure.	
104. Ditto	–	–	Two stones.	Cure.	

In the 104 cases tabulated above, 31 were fatal, or somewhat less than 1 in 3.

The age of the patient makes no great difference in the result, for—

In 38 cases under 20 years, 9 were fatal.
In 8 cases between 20 and 50 years, 3 were fatal.
In 19 cases from 50 to 70 years, 5 were fatal.
In 18 cases above 70 years, 6 were fatal.

The cause of death appears to have been generally peritonitis or infiltration of urine into the loose cellular tissue about the bladder.

Maund is said to have lost only 5 patients in 40 operations ; and of 100 patients operated on by Frere Côme, no more than 19 are reported to have died. These results are so favourable that I have been unwilling to admit them into the general estimate.

The average mortality after the lateral operation is 1 in 7, or $7\frac{1}{2}$. Thus the high operation is more than twice as fatal as the lateral, which is sufficient reason for rejecting it under ordinary circumstances. But it is well known that the success of the lateral operation varies greatly with the size of the stone; so much so, indeed, that of twenty cases operated on in the Norwich Hospital, in which the stones weighed more than three ounces, only eight recovered. It seems that the dangers of the high operation do not increase in so great a ratio with the size of the stone, for of twenty-one cases, where the stone weighed more than three ounces, fourteen recovered. It was from the comparison of the two operations made in this manner, as well as from the consideration of the great difficultics of the lateral method, when the stone is large, and of the evils of the laceration and bruising of the soft parts necessarily occasioncd in extracting it entire or in breaking it up, that we determined on making the incisions above the pubes in the case above related, and I should be induced to follow the same course in other instances, where there may be good grounds for believing that the stone is of very large size.

I think that the high operation is to be preferred to the recto-vesical; because the dangers of the latter are as great, the mortality attending it being at least as high, and it is, besides, attended with a liability to the persistence of fistula between the bladder and rectum, and to the division of the seminal ducts on one or both sides. I should say that I found the high operation difficult, on account of the depth of the bladder from the surface and the fear of injuring the peritoneum in carrying the knife down to it, as well as from the tight manner in which the stone was grasped by the bladder. This latter circumstance occurring in other cases has probably given rise to the idea that the stone was adherent to the mucous membrane of the bladder. M. Souberbielle relates that this adhesion had taken place in several of the cases operated on by himself, and he makes the liability to this cvent an argument in favour of the incision above the pubes. It is most probable that he was, sometimes at least, deceived by the close contraction of the bladder upon the calculus.

It has been the practice of most operators to distend the bladder with water before commencing the incisions above the pubes. This is often attended with much difficulty; and as I had on

several occasions performed the operation on the dead subject without wounding the peritoneum, when the bladder was empty, and had observed the rapidity with which any quantity of urine that happened to be contained in the bladder soaked into the loose cellular tissue of the pelvis as soon as an incision was made through the coats of the organ, I determined on endeavouring to avoid the great dangers that are likely to result from infiltration of urine by emptying the bladder before I commenced the operation, and by introducing the syphon afterwards. It has been seen how completely these intentions were frustrated by the escape of a large quantity of urine when the bladder was opened, and by its continuing afterwards to pour out in gushes through the wound. There can be little doubt that this urine was contained in the ureters and pelves of the kidneys, which had become dilated, in consequence of the mode in which the calculus filled up the cavity of the bladder.

We cannot but suppose that infiltration of urine took place to some extent; and it is surprising that no bad symptoms, no peritonitis, and scarce any sloughing of the cellular tissue, were occasioned by it. I have, in one or two cases, been astonished at the slight injury that was produced by the escape of urine into the cellular tissue. In one instance, which is strongly impressed on my recollection, when I was endeavouring to pass an instrument through a stricture causing severe and complete retention, suddenly, in consequence, no doubt, of some injury done to the passage, the escape of urine into the perineum and scrotum was evident from the swelling of that bag and of the penis. It took place rapidly, under my own eyes, was extending to the fore-part of the abdomen, and would have gone much further had not I immediately placed the patient in the same position as for lithotomy, and cut down upon the membranous part of the urethra, as well as made free incisions in the scrotum. In this case, although the infiltration of urine had proceeded to a considerable extent, the sloughing of the tissue was very slight, and was confined to the immediate neighbourhood of the incisions. I do not know how to explain this occasional exemption from the disastrous results which generally follow the escape of urine from the bladder into the adjacent cellular tissue of the pelvis and scrotum.

Cysts in the Kidney.

AN ESSAY

ON

TUBERCULOUS DEPOSITION IN THE KIDNEY.

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THIS Essay was written in the spring of 1849, and read at Hadleigh, in June, before the members of the Provincial Medical and Surgical Association; the morbid preparations and microscopical objects, illustrative of the subject, were also exhibited, and are now in my possession.

Not only did the comparative rareness of the disease urge me to bring this paper before my brother members, for I was also very anxious to contribute the results of long research in the microscopic anatomy and pathology of tubercle to these *Transactions*, believing that efforts, however humble, to elucidate the course of this noxious adventitious product, would receive some attention.

In this Essay there will be found descriptions and cases of tuberculous deposit in the kidney, in all stages of the disease. The microscope used was a Powell, and the power employed was of 200 to 600 diameters; it had been well tested whilst I was Prosector in Physiology at King's College, London.

As an appendix, there are some remarks upon the pathology of cysts of the kidney.

We find three structural elements in healthy kidneys, viz., blood vessels, uriniferous tubes, and a fibrous structure, the matrix binding these together.

The uriniferous tubes radiate on all sides from the pelvis of the kidney, being at first straight, and associated in masses, where they form the mammillary processes and medullary cones or pyramids,

and subsequently separated, and running a serpentine course in the cortex of the organ. Each tube terminates by enclosing an arterial tuft.

The blood-vessels enter the kidney between the mammillary processes, pass up, and break into their ultimate terminations, in the midst of the tubes of the cortex.

Each uriniferous tube is composed of a thin, transparent, homogeneous membrane, which sustains internally epithelium cells, and which is in contact externally with the fibrous tissue or matrix, which binds the tubes together. Each tube is continuous with the genito-urinary mucous membrane at the mammillary process, and presents different appearances in its course. In the medullary cones or pyramids, we find straight tubes with a scale-like epithelium; in the cortex, convoluted tubes and epithelium of the globular variety, nucleated and slightly granular.

It has been already noticed, that the blood-vessels enter between the associated tubes forming the medullary cones; now, the arteries pass into the cortex, and there break up into capillaries, each of which terminates by being formed into a knot-like convolution, called a malpighian tuft. Every malpighian tuft is enclosed by the basement membrane of an uriniferous tube, the bulb-like form resulting from the knot-shaped arterial tuft and its covering of membrane, receiving the term malpighian body. One venous twig results from each malpighian tuft, it passes through the enclosing membrane, near to the entrance of the artery, and joining with others in the immediate neighbourhood, helps to form a venous plexus, which is closely applied to the outside of one or more tubuli uriniferi.

Any injection thrown up an artery will pass into the cortex, will enter the malpighian tuft, and pass out by the vein; but if too great injecting force be used, the malpighian tuft will be ruptured, and its contents poured into the uriniferous tube, whose basement membrane enclosed it.

The tubes and blood-vessels are kept in situ by a white fibrous tissue. If a section of a kidney be made transverse to the course of the tubes, and then be washed out by a gentle stream of water, the fibrous matrix will be well seen.

A well prepared section presents a reticulate appearance, under moderate microscopical powers,—reticulate, for the tubes when

washed out, leave open spaces bounded by this structure. There is great variation in the size of the open spaces, which are surrounded by the fibrous tissue; and this variation depends upon the occasional obliquity of a tube, and oftentimes upon the presence of a malpighian body, which, being at least twice the size of a tube, causes a corresponding increase in the area of the open space. The blood-vessels leave slight openings. This matrix, which consists of delicate interlacing fibres, without any cell growth, except that of developing fibrous tissue, is very important in a pathological sense; it is analogous to the intercellular structure of the lung, and, like it, becomes too frequently the seat of abnormal changes.

According to Bowman, the malpighian tuft allows the watery part of the urine to escape through the capillary walls into the tube, and the vein which results from the malpighian tuft, when associated with others, in the venous plexus which surrounds every tube, secretes or rather transmits to the epithelium of the tube the wherewithal to produce the urea, uric acid, and the other constituents of the urine.

The urine, then, results from a secretion on the part of the malpighian tuft, and from the elimination of certain principles from the venous plexus, by means of the epithelium.

It is easily comprehended, that if there be any impediment to the return of the venous blood from the kidney, the malpighian tuft will become distended, and after a while will pour out pure serum, more or less mixed with blood corpuscles and the usual amount of water; also, that if the tube be blocked up, or its caliber encroached upon in any one spot, the portion between the obstruction and the malpighian body will become distended with urine, and subjected to a force acting in all directions upon the interior.

Case 1.—A boy, of thirteen years of age, had an attack of enteritis. I saw him subsequently, with Mr. Clark, of Colchester. He then complained of pain in the region of the cæcum, increasing on pressure; had a rough dry skin and a raw looking tongue. The right side of the chest was duller than the left, and the respiratory murmur healthy, but rather weak and indistinct. He had a rapid pulse, and passed his urine frequently and in small quantities. He died with symptoms of peritonitis, from perforation. On opening him, we found a perforating ulcer of the cæcum, a

tubercular peritoneum, and adhesion of the right lung to the corresponding side, and crude tuberculous masses beneath the pleura, covering the lung; lungs and heart healthy.

The bladder was half filled with urine, and the glands usually found accompanying the iliac veins were much enlarged, indurated, and infiltrated, with tubercle.

The kidneys were of the proper size, flabby, and had their pelves and ureters greatly dilated and filled with urine. A section showed that the pelvis of either kidney occupied a much larger space than usual; and, to the naked eye, the whole of the other structures appeared healthy. But on making a thin transverse section of one of the pyramids (medullary cones), and on washing out the tubes, so as to obtain a good view of the matrix, I found myriads of tubercle cells, replacing, not super-added to, portions of the proper tissue. None of these cells were found in the uriniferous tubes, they simply replaced the fibrous tissue of which the inter-tubular spaces or matrix is composed. The uriniferous tubes in the neighbourhood of these deposits, which were numerous, small, and isolated, had not suffered any diminution in caliber from pressure, but were filled with highly fatty epithelium. In those parts of the tubes which were remote from the deposits, the epithelium was healthy.

A magnifying power of 600 diameters showed the tubercular cells to be more or less globular, refractile, with well-defined margins, and to contain one or more highly refractile granules; no nuclei could be seen, and water after a while rendered the general contour of the cells irregular. Acetic acid rendered other granules apparent within, but had no effect upon the cell wall. The cells were aggregated, never solitary, and were surrounded by a faintly granular cytoblastema; neither pus nor exudation or blood-cells were found amongst or near the deposits, but the neighbouring fibrous matrix was friable, and easily resolved into separate fibres.

The dilated condition of the ureters and pelves could be readily accounted for by the long-continued pressure from within outwards they must have suffered. Each ureter passed over the enlarged lumbar glands on its passage to the bladder, which, as it became filled with urine, rested upon these glands, and necessarily pressed upon the ureters. The kidneys continuing to secrete, the urine was stopped in its passage until the pressure upon the ureters was

relieved by the bladder being emptied; a great dilating force was thus, at certain periods, influencing the ureters and pelves, which gradually increased in caliber, and, as is frequently the case, when the obstruction to the passage of urine is in the urethra, in long-standing strictures, for instance, would have, after a while, tended to the disorganization of the kidneys.

I was induced to examine the kidneys of this patient, in order to see what effect the force, which had so dilated their pelves and ureters, might have had upon the uriniferous tubes. They appear not to have suffered. The deposits of tubercle, which were found both in the cortex and in the medullary part, were invisible to the naked eye, and were accidentally discovered during some examinations of the matrix. The deposits were evidently secondary to those in the chest and abdomen, and consequently more recent; and the fluidity of the cytoblastema, the absence of those constituents, of cholesterin, for instance, which are found in tubercular deposits of long standing, and the readiness with which the cells were influenced by water, (by endosmosis and exosmosis), lead one to imagine that these deposits were comparatively new, and that a few days before death the cytoblastema alone existed, the cellular element being evolved subsequently to its deposit.

In no part could any tubercular deposit be discovered within the uriniferous tubes; wherever it existed it was external to them, amongst the venous plexus which surrounds them, and contributes the wherewithal from which their epithelium and its contents are formed. There were evidences of a bad state of the nutrition of the fibres of the matrix in the vicinity of each of the deposits, and the epithelium of those of the uriniferous tubes which corresponded to the portions of the matrix, replaced by tubercle, was fatty. This abnormal state of the epithelium, depended upon the presence of an adventitious product, for above and below the tubercular deposit no fatty epithelium was to be seen.

The fact of the plasma, whence the contents of the epithelium cells are derived, having to transude, or come in contact with a product typical of the existence of a perverted state of the nutrition of a part, accounts for the quantity of a lowly organized fat within them.

Case 2—Occurred in the Colchester Hospital. A man, Johnson by name, and forty-six years of age, was admitted whilst suffering

from intense dyspnœa, produced by an encysted pleuritic effusion on the left side, and a congested state of the upper part of the right lung. After his death we found, besides the above-mentioned effusion, miliary tubercles, surrounded by engorged tissue, in great abundance, in the right lung; we found, moreover, tubercular deposit in the liver, spleen, beneath the mucous membrane of the alimentary canal, and considerable swelling and induration of the mesenteric glands.

The kidneys were flabby, marked on the surface with star-shaped veins, and presented, both in the cortical and in the medullary portions, numerous specks of a tissue foreign to the organ.

A careful microscopic examination discovered the existence of a great quantity of cells like those seen in Case 1,—cells without nuclei, containing one or more refractile granules, and more or less irregular in their outline; also, a few cells, much larger than the above, containing many refractile globules, which, on escaping from the cell-membrane, proved to be of the same size, and to have the same characters as those which in immense numbers surrounded the cellular structures, and in fact constituted the bulk of the deposit; also, cells with ill-developed nuclei, which were granular, and had not a defined outline. These cells were few in number, and frequently presented a central constriction, and appeared as if about to undergo fissiparous division. The rest of the deposit consisted of large oil globules and plates of cholesterin.

Here again, as in all the cases I have observed, the tubercular deposit in the kidney was secondary to that in the lung, and was found in the matrix, and not within the tubular structures of the organ. These last were affected by the deposit in the same manner as they were in Case 1, and more than one shape of cell was found. Irregularity of shape is one of the peculiarities of the lowly organized epigenisis, called tubercle; and those who look in deposits of it for regularly shaped or for special cells, will, unless these deposits are very recent, look in vain.

In the cytoblastema of tubercle, cells of a certain definite form are first developed, but subsequently there is a tendency towards the development of cells possessed of but slight mutual resemblance. In the case before us the cells of the second variety were simply those of the first kind much enlarged; but there were others in which a step towards a higher grade of cell-structure was made;

there were a few cells with ill-developed nuclei, and these cells were occasionally undergoing fissiparous development.

The cytoblastema in this deposit was colourless, and contained a great quantity of highly refractile granules, in which the phenomena of molecular motion was well seen.

Case 3—Occurred lately, in the Colchester Hospital. A girl died in the last stage of phthisis pulmonalis. On nearly all of the mammillary processes of either kidney, a slight opaque looking deposit of tubercle was found. Both organs were larger and softer than usual, and the cortical portions exhibited here and there a granular appearance; a few small cysts were found in the medullary cones (pyramids), and near their junction with the cortex. The tubercular deposit was hard and gritty, translucent in its most dense part, which was near the apex of the mammillary process, and immediately beneath the pelvic mucous membrane; it was more opaque where it was softer, near the spot where the medullary cone may be said to commence. The microscopical appearances of the hard and of the softer deposits differed. The harder and semi-transparent deposit presented, under a power of 600, a faintly granular transparent tissue, in which no specific structure could be made out, with the exception of sundry very much altered uriniferous tubes; also, a few ill-shaped non-nucleated cells. The softer portion consisted of the debris of cells, of irregular non-nucleated cells, of numerous highly refractile globules, of much oil and cholesterin. Numerous altered tubes passed through it, but none of the transparent stroma of the hard portion was to be seen. The mammillary processes were not larger than usual.

In those portions of the cortex which appeared granular, tubes, stuffed with epithelium, and malpighian tufts, covered with a greater amount of cell-growth than usual, were found, and in some spots perfect destruction of the malpighian tufts and their replacement by exudation granules, were well seen.

In the harder part of the tubercular deposit, an attempt was evidently being made towards the production of a deposit, like that of a hard semi-transparent nature, so frequently seen in the lungs, and which has a much less tendency to soften and influence the surrounding tissues than the softer and more cellular variety. The progress of a tubercle in which there is a dense amorphous stroma in addition to the cell-structure, is much slower than that of one

in which it is not found. The probable duration of both, bears some analogy to the comparative duration of scirrhus and encephaloid; the one slow in its progress, and consisting principally of a fibrous element, the other rapidly fatal, and possessing a superabundance of a cellular element, whose paucity is peculiar to the scirrhoid variety of carcinoma.

In the softer and more recent part of the deposit, changes were going on which are the first step towards the softening, and consequent elimination of the adventitious product. Detritus of cells, their contents, oil globules and an inorganic substance, cholesterin, indicated that the little vitality with which tubercle is endowed was gone, and that the organized part of the deposit had resolved itself into more remote principles, and was able to act upon the surrounding tissues more than ever as a foreign body.

The cortex and the medullary cones which corresponded to the diseased mammillary processes, were the seat of numerous cysts. No cysts were found in those medullary cones whose mammillary processes were healthy. The cysts were small, varying in size from a pin's-head to the size of a mustard seed, and contained a brown viscid fluid, in which oil, cholesterin, and the debris of epithelium cells, were found. Nitric acid produced crystals of nitrate of urea when it was added to the fluid and suffered to evaporate. Sections of the matrix in the neighbourhood of the cysts showed the tubes to be greatly dilated, and that it was itself greatly encroached upon. The dilatations of the tubes were singularly evident, their epithelium was very scanty, and occasionally small cysts, with considerable condensation of the matrix around them, could be seen. Nearer the tubercular deposit, the changes in the tubes induced by it, were very remarkable; as they approached the deposit their epithelium, as in the other cases, became very fatty, and higher up, although not fatty, yet the tubes were crammed with epithelium. When surrounded by the softer deposit, the tubes suffered slightly from compression, and occasionally their epithelium was seen broken down, and many fat globules free in the tubes. As the tubercular deposit became denser many tubes became obliterated, others lost their continuity, or, when this was not the case, suffered much compression, contained no epithelium cells, but were filled with a refractile fluid, which gave them a singularly distinct appearance, in the midst of the dense amorphous stroma

which surrounded them. This refractile fluid was soluble in sulphuric ether, and consisted of the oil globules formerly held within the epithelium, but since its destruction escaped free into the tube, and coalesced. Several of these compressed tubes presented at various distances, constrictions which encroached upon their caliber to a greater or less extent, being caused by the irregular growth and consequent pressure of the inter-tubular tubercular deposit; others had in part been obliterated by the same means, and those whose continuity had been interfered with had suffered unequal pressure at different and more or less distant spots, corresponding deficiencies of the tubular structure being discovered, so that where there was once a tube filled with refractile fluid, as just described, there is now a linear series, of more or less ovoid lacunae, still containing the refractile fluid, and being, of course, isolated portions of compressed uriniferous tubes. The denser part of the tubercular deposit was at the apex of the medullary cones and mammillary processes, and as there the tubes are parallel so were these ovoid lacunae found in parallel series, each series being more or less linear, and the track of a formerly healthy tube. The lacunae consisted of basement membrane, enclosing oil.

Case 4.—A pauper in the Colchester Union was examined by Mr. Clark and myself. He was upwards of sixty years of age, had been bed-ridden for many months, and had died from white softening of the brain. Three of the mammillary processes of the right, and two of the left kidney, were the seat of a pale yellow gritty deposit, which at first sight appeared to be within the tubular structure of the organ, but which, on more careful examination, was found to be external to it, and in the meshes of the matrix.

This deposit, although very scanty, had obliterated and otherwise affected the uriniferous tubes in its neighbourhood; it consisted of much inorganic matter, crystals of cholesterin, oil globules, myriads of spheroidal refractile molecules, occasional cells without nuclei, but containing one or more granules, and of a trace of the dense semi-transparent structureless tissue, so frequently mentioned in the last case. The partially obliterated tubes contained either the refractile fluid found in the last case, or numerous large irregular crystals, but no trace of fatty epithelium could be found.

Between the obliterated portion of some of the tubes and the malpighian body a series of dilatations existed, apparently wherever there had been a turn in the tube, or between two meshes of the dense fibrous matrix.

A low microscopic power distinguished these rows of dilated portions of tubes, until they became more confused and less regularly parallel in the cortex; here, however, several small cysts existed, which contained a reddish-yellow, thick, gelatinous fluid, in which cholesterin and the debris of epithelium cells could be traced.

The presence of the non-nucleated cells particularized the character of the deposit in this case. The adventitious product was tubercle, which had undergone, to a certain extent, calcereous degeneration,—a step towards a cure. Hard gritty masses were found here and there in the lungs; but his death was caused by a diseased state of the vessels of the brain. From a careful microscopic examination of calcereous tubercular masses in the lung and in the larger glands of the neck, I am satisfied that the ammoniaco-magnesian phosphate, the carbonate and phosphate of lime, the cholesterin, and free oil globules, are produced from the contents of the cells of the tubercle, after the rupture of the cell wall. Nothing is more common than the presence of debris of cell structure in all parts of these gritty and transformed epigeneses, and we have no reason to believe that these inorganic substances are deposited by crystalization from the serum or from the colourless plasma of the blood.

Case 5.—A man, between forty and fifty years of age, Dyer by name, and a patient of my colleague, Mr. Waylen, suffered from urethral stricture and from tuberculous disorganization of the left testicle. His general appearance led one to believe that he had serious internal organic disease, whose seat was declared to be in the kidneys, inasmuch as he passed albuminous urine, epithelium cells loaded with fat globules, and pus. The urine, when he first entered the Colchester Hospital, was generally neutral or faintly alkaline in its action on turmeric paper, but subsequently it became very offensive, contained much earthy phosphate, and diminished rapidly in quantity. There were no evidences of heart, lung, or liver disease; dropsy did not supervene; he died from the

effects of a series of abscesses, which formed about the internal inguinal ring, one of which communicated with his bladder.

Post-mortem.—Brain, organs of circulation and respiration, healthy; liver and spleen slightly enlarged, otherwise as usual; nothing abnormal existed in the alimentary canal, the disease being confined to the genito-urinary apparatus; the urethral stricture was narrow, tortuous, and cartilaginous; the affected testicle was found a shapeless semi-purulent mass, separated from the cord, and contained in a more or less ulcerated tunica vaginalis. The abscesses about the inguinal rings communicated with each other by fistulous passages; the bladder had contracted adhesions with the peritoneum above and on either side of the pubic bones, and had been opened from without by one of the numerous superficial abscesses; it was much larger and softer than usual, and near the artificial opening, semi-gangrenous. The kidneys were frightfully diseased, the left more so than the right, being three times its usual size, covered with irregular rounded elevations of all sizes, denoting the presence of cysts, and the whole organ was softer and much heavier than usual. On opening the pelvis of this kidney, its mucous membrane was found greatly thickened by a deposit of tubercle beneath its basement and in the cellular tissue, between the fibrous and mucous coats. This tubercular deposit was in irregular patches, generally covered by the mucous membrane, whose large squamoid cells contained large fat globules, but occasionally destitute of it, and the seat of ulceration; the ureter was impervious. On making a section of the kidney through its cortex and tubular structure down to the cavity of the pelvis, great confusion of the structural elements was found to exist; the mammillary processes had been destroyed, the greater part of each medullary cone was the seat of tuberculous ulceration, cysts of all sizes were to be seen in all parts of the organ, some of them having been partially destroyed by the progress of ulceration, and the greater part of the upper quarter of the kidney was resolved into a large abscess, which had not yet burst into the pelvis.

No distinction could be made between the cortical and tubular structures. The ulcerating surfaces of the medullary cones were irregular, and covered with a dense flaky pus, consisting of pus cells, exudation corpuscles, debris of epithelium cells, and numerous fat globules and granules; the surfaces of these ulcers

differed much from the surrounding tissues, in colour, density, and structure; they presented to the eye a dense white cheesy-looking layer of the depth of a quarter of an inch, whose free surface was covered with the above-mentioned pus, and whose other was in contact with what remained of the medullary cone. Evidences of tubercle in all its stages were found in this white layer, and of rudimentary tubercle in the apparently healthy medullary structure beneath it. Near to the white margin, the uriniferous tubes were found slightly compressed by the deposit of those refractile cells which distinguish freshly deposited tubercle, and by the granular cytoblastema surrounding them; the fibrous matrix had disappeared, these new structural elements having replaced it. A little further off from the white layer than where these last-mentioned alterations existed, the tubes were found healthy, as regards their contents; they suffered occasional bulgings, and as they passed on to the cortex, were formed into series of cysts. Surrounding the small portion of the tubes which still remained healthy, the matrix was dense, its fibres occasionally separable one from another and distinctly nucleated, but there were no evidences of the presence of an adventitious product.

The following were the microscopical appearances of the white stratum beneath the ulcerating surface, passing from the healthy structure to the surface: the globular refractile non-nucleated, but granular cells, and dense granular cytoblastema, before mentioned; compressed tubes, with apparently healthy epithelium, which was, however, by no means constantly adherent to the basement membrane. Then a section nearer the surface produced: the same kind of cells, the cytoblastema appeared to be denser, debris of these cells, crystals of cholesterin, fat globules, and a few cells, irregular in outline, and containing a nucleus, which sometimes appeared to be suffering fissiparous division, and many small and highly refractile granules.

A section immediately beneath the ulcerating surface gave, debris of cells, immense quantities of small granules, numerous plates of cholesterin, much fat, and some of the irregular cells just mentioned, but in which nuclei were rarely found. The surface of the ulceration presented pus globules, granules, exudation cells, fat globules, and much detritus of cell structure.

As the uriniferous tubes became surrounded by these new

structures, their caliber became greatly diminished, until at last, two parallel and rather wavy dark lines, was all that could be seen of them.

The increased diameter of some of the tubes in the portions of the medullary cones which remained healthy was remarkable, many of the tubes being several times larger than usual, and having but little epithelium, so little, that where the dilatation was considerable it could be only distinguished as a feint layer within the basement.

With a low magnifying power, dilated tubes could be traced, at first running parallel, and then becoming contorted and further dilated, until the continuity of any one tube could no longer be ascertained. Towards the circumference of the gland but few healthy tubes could be seen, but those suffering from all degrees of dilatation, and cysts of all sizes, were in great plenty.

A careful section of the matrix at this part showed how much larger the area of its meshes was than usual.

Case 6.—Henry Thurton, aged 35, a patient in the Colchester Hospital, died under my care, in the last stage of phthisis pulmonalis. The autopsy revealed ulceration of the larynx, small ulcers in the mucous membrane of the trachea, numerous cavities in the lungs, a tubercle in the right lobe of the liver, tubercular deposit in the spleen, mesentery, and in both kidneys. During life he had frequent dull pains in the region of the left kidney, and passed during the whole time he was in the Hospital, a small quantity of urine daily, highly lithic, and containing a small quantity of pus. The left kidney large and flabby, presented near its upper part, on the posterior surface, a white and somewhat hard patch, of the size of a small pea, gritty centrally, it became softer towards the circumference; it was not surrounded by a false membrane, nor were there any pus or exudation cells in its neighbourhood, but the adjacent uriniferous tubes were crowded with epithelium.

The deposit was of yellow tubercle, and consisted of myriads of non-nucleated cells, of more or less irregular outline, and containing three or more granules, of detritus of cell-structure, of fat, and much inorganic matter.

On three of the mammillary processes there were spots of tubercular deposit, whose general characters resembled those described in Case 3. The uriniferous tubes suffered from the pressure

consequent on the presence of these new growths, and presented in a singular manner the appearances described in the third case.

The mucous membrane of the pelvis of the kidney was highly vascular, and contained a quantity of muco-purulent fluid.

The right kidney had tuberculous spots on two of its mammillary processes. Neither organ was the seat of cysts.

In each of these cases there was a structure developed in the kidney, which ought not normally to enter into its composition,—a structure deposited, first of all, as a colourless blastema, in which cell-growth subsequently occurred; the cells differing in external appearance from any of the histologic elements of the kidney, and resembling those which are known as characteristic of tubercle in other organs of the body.

It is sufficiently evident, that any researches into the nature of tuberculous disease of the kidney, can only be interesting in a pathological sense, that the disease can hardly ever be suspected during life, and that on account of the serious diseases to which it is secondary, we are never called upon to treat it.

The bibliography on the subject of tuberculous disease of the kidney is very scanty; but before giving any abstracts from the works of those who have written on the subject, it would be as well to mention, that many authors have mistaken scrofulous degeneration of the kidney for the disease treated of, in this Essay. So much has been written and spoken on the identity or the contrary of tuberculous and scrofulous disease, that no mention of the arguments employed, *pro* or *con*, need be made here. The question hangs upon the definition of tubercle and scrofula; the same definition will not hold for both diseases. In tubercle there is a special and characteristic cell-growth, such is not the case in scrofula; the diseases are frequently associated, but their pathology is widely different.

Scrofulous abscess of, and the changes induced in, the kidney by that perversion of its nutrition called scrofula, are by no means uncommon, but no special cell-growth is to be found; the microscope discovers, besides the usual products of inflammation, a quantity of more or less homogeneous lymph, in which exudation corpuscles and oil globules exist.

In scrofulous abscess of the kidney the glandular structure is rapidly destroyed, and the interlobular cellular tissue, thickened by

deposit of lymph of a lowly organized nature, forms numerous septa, which separate the huge abscess into so many divisions.

Schoenlein, in his clinical lectures, gives some interesting remarks upon scrofulous disease of the kidney; but it will be seen that he confounds this disease with that more particularly treated of in this Essay. He says, "this malady is one of great rarity; I have not seen six cases of it, at least where there has been a fatal termination. Although I believe it to be curable at the beginning, after it has reached a certain stage it is beyond the power of art. It is therefore important for the practitioner to be able to detect its presence. The primary phenomena closely resemble those of incipient pulmonary phthisis. Young persons are most prone to be attacked, as children of from 7 to 8 years old, even up to the period of puberty, who are of a strumous habit, or present marks of strumous affection of the external parts. Such individuals manifest, generally after exposure to cold and moisture, an affection of the urinary organs, at first indistinct, a feeling of pressure in one or both regions of the kidney, pain in the sacrum, rarely darting; on further examination it will be found that the pain is referred, not to the middle, but to the side of the vertebral column; there are frequent calls to void urine, especially during sojourn in a cold and damp atmosphere. I have perceived that this urgency of micturition was aggravated at night, just as the cough in the instance of pulmonary tubercles; young children are apt to wet the bed, hence this habit ought to be watched when they are of a strumous disposition. The urine is, in the outset, pale, limpid, or else turbid from mucus, very like the tracheal secretion coughed up by phthisical patients at an early stage. Only when violent pain sets in, will blood be discovered in the urine—periodical hæmaturia (akin to hæmoptysis). In individuals nearer puberty other symptoms are added, as erections, and painful retractions of the testicles, like what occurs in cases of stone in the bladder. The above are the characters of tubercular disease of the kidneys while susceptible of cure. The treatment ought to consist of local depletion, frictions with iodide of potassium or iodide of mercury, over the region of the kidneys, saline baths, iodine internally, by itself or in mineral waters, with great attention to diet and drink—the last ought to be ass's or goat's milk mixed with mucilage."

Rayer ("Traité des Maladies des Reins," &c.,) whilst he remarks

that renal tubercles are less rare than is generally believed, observes that they are far from being of frequent occurrence. He gives no accurate description of the disease, and shows how doubtful is its diagnosis.

Louis, in his immortal work, asserts that tubercle of the kidney is always secondary to a like deposit in the lung, and that he found a small quantity of tuberculous deposit in the kidneys of four out of ninety cases of phthisis pulmonalis. But out of 500 cases in which there was no phthisis, he did not find a single case of tuberculous kidney.

G. Johnson ("Cyclopædia of Anatomy and Physiology, Art. Ren.,") describes and gives a drawing of scrofulous abscess of the kidney.

Andral ("Précis d'Anatomie Pathologique," p. 638,) mentions that the existence of tubercle in the kidney is rare, that it is usually secondary, and that once he found a large mass of tubercle in one kidney, without there being any like deposit elsewhere.

Dr. Christison ("Library of Medicine") says, "Tubercles may affect either the membranes of the kidneys or their substance. They vary in size from that of small grains to that of an olive; and they are commonly granular, and grouped among the tubuli, but large and detached in the cortical texture. Tubercular kidneys are seldom much enlarged, unless the tubercles obstruct the papillæ (mammillary processes) or ureters, and cause distension; they are seldom contracted in size. Tubercles of the kidneys, sometimes undergo softening; and occasionally they ulcerate and establish a communication with the colon;—they are most frequent in adults, rare in infancy and old age; and they are seldom found in the kidneys without having been also in other parts of the genito-urinary apparatus, and likewise in the lungs; the symptoms are obscure and dubious."

In Phillips's excellent work on scrofula there is a drawing by Vogel, representing tuberculous matter taken from the kidneys; the magnifying power is stated to have been 220 linear. The size of the cells delineated and the invariable presence of large and well-formed nuclei in them, prove that this usually very correct pathologist was mistaken in the identity of the morbid (?) product he described.

The cases which I have described were under my eye for some

time before death, and in three out of the six there were symptoms of renal disease, but in one only had I any suspicion of the presence of tubercle in the kidney. In Case 6, where there were evidences of tuberculous ulceration of the larynx and lung, there were also symptoms of disease of the left kidney, inasmuch as the patient suffered from occasional attacks of acute pain in the region of the left kidney for some time before his death. His urine was highly lithic and at last contained pus, but never was albuminous. He never suffered from vomiting.

There could be no mistake about the symptoms of disease of the kidneys in Cases 1 and 5, but there were no signs of tuberculous disease of these organs. It would appear, then, that we have a certain right to find tuberculous deposition in the kidney, when, in cases where there are evidences of extensive tuberculosis, there is also acute pain over one or both renal regions, and when, at the same time, the urine contains any of the products of inflammation, the bladder and urethra being healthy.

There is no doubt but, now that the attention of this Association has been directed to the study of tuberculous affection of the kidneys, many cases of it will be brought to light. It is very requisite that care should be taken so as not to mistake earthy deposition, such as occurs frequently in gout, for instance, within the tubular structure, for tubercle.

The following is a summary of the six cases :—

No.	*Sex.*	*Age.*	*Situation of Deposit.*	*Nature of Deposit.*	*Symptoms.*
1	Male	13	Pyramids	In the earliest stage	Existed.
2	Male	46	In all parts	Mature and degenerating	None.
3	Female	22	Mammillary processes	Ditto ditto	None.
4	Male	60	Ditto ditto	Calcareous degeneration	None.
5	Male	45	All parts	All stages	Existed.
6	Male	38	All parts	Mature and degenerating	Existed.

In these six cases there was every evidence that the tuberculous deposit was developed in those situations most eligible for its production on account of their vascularity; it was invariably found between the uriniferous tubes, replacing, or in intimate relation with, the fibrous matrix. The interior of the uriniferous tubes was never found to be the seat of either the cytoblastema or of the cell-growth of tubercle.

The epithelium of the tubes (except in Case 5) suffered in a peculiar manner from the presence of the tuberculous deposit, being fatty in its immediate neighbourhood, and frequently healthy or merely in excess in those parts at a distance from it.

This is an interesting fact, for it throws a little light upon the pathology of morbus Brightü, or rather upon that disease of the kidney which is characterised by the association of albuminuria with fatty epithelium, and which has been so well described by my friend, Dr. George Johnson.

In this disease epithelium cells, loaded with fat, are found floating in urine of a low specific gravity, and more or less albuminous; the kidneys have every appearance as if suffering from a perversion of their nutrition, and fatty epithelium is found very generally in the cortical portions of the organ. There is an obstacle to the return of the blood from the malpighian tuft, whose consequent congestion is relieved by a filtration through the arterial walls of serum holding a certain amount of fibrin in solution; the fibrin coagulates in the tubes, and is passed out with the urine, in the form of casts of their interiors, the serum is mixed with the urine, and its albumen is precipitable by many reagents. It is tolerably evident that the ultimate causes of the deposition of fat within the epithelium cells and of the retardation of the blood in the malpighian tuft, are identical.

The epithelium cells owe their existence to the colourless blood plasma, they and their contents are produced therefrom, their fitness for the offices they fulfil, depends upon the quality and quantity of the formative fluid.

Now, in Case 1 the epithelium was healthy everywhere, except where there was an adventitious deposit around the blood-vessels, which gave the wherewithal to form the cell-wall and contents of the epithelium. The epithelium supplied from the contents of these vessels, which were thus surrounded by a deposit indicative of their suffering from a state of disordered nutrition, was unhealthy, was fatty. The cell chemistry was unable to evolve any higher principle than the lowly form of fat or oil.

Albuminuria with fatty epithelium may, then, with some degree of probability, be attributed to a diseased state of the blood-vessels of the kidney, together with a cachectic state of the whole body, more or less influencing the production of such diseased state.

I have not been able to satisfy myself as to the state of the blood-vessels in contact with tubercular deposit in the kidney, but by analogy they may safely be said to be more or less the seat of atheroma; by analogy, for in tubercular glands of the axilla and neck, the diseased state of the vessels, not yet obliterated by the adventitious deposit, can readily be seen.

It is worthy of notice that even the epithelium of the pyramids, and of the tubes of the mammillary processes, was fatty when influenced by neighbouring tubercle, and that in Case 5, where there was no fatty epithelium in the tubes, even in the vicinity of the deposit, yet the squamoid cells of the mucous membrane of the pelvis of the kidney were loaded with oil, they being in close relation with a layer of tubercle.

In Cases 3, 4, and 6, the tubes had suffered such pressure from the surrounding tuberculous deposit, that the fat of their epithelium had coalesced, and this was particularly seen, when the lower ends of the pyramids and the mammillary processes were the seat of the deposit.

It has been mentioned, that the tuberculous deposit was invariably found between the tubes, and that it either replaced or was in intimate relation with the fibrous matrix. Generally speaking, the tuberculous masses had obliterated by pressure, and had then occupied the place, more or less, of the matrix, but in the earliest stage of the deposits, the fibres of which the matrix is composed, and the blood-vessels, whence it is nourished and the blastema, whence tubercle is developed, still existed.

The following appears to be the progress of the development of, and the phenomena induced by, the presence of tubercle in the kidney. A greater or less quantity of colourless plasma (serum holding fibrin in suspension) is effused by the capillaries which run between the tubes and amongst the fibres of the matrix. The effusion at first scanty and invisible to the naked eye, necessarily bathes the fibres of the matrix and the blood-vessels in its immediate neighbourhood; it is in contact also with one or more uriniferous tubes. The plasma is at first homogeneous, but granules soon become apparent in it, subsequently many of these granules become enclosed in cell-walls, and the tubercular deposit then consists of a more or less fluid plasma, granules, and cells containing granules. During this cell-growth, more or less

condensation of the effused product occurs, the blood-vessels and fibres of the matrix, which formerly were surrounded by it, are absorbed, the absorption being induced by the pressure incident upon the condensation. The uriniferous tubes are pressed upon, as the tuberculous mass increases in size, from fresh deposition of plasma and necessarily, of cell growth. It is evident that all increase of dimension in tubercle must take place by deposition around the original mass, and from vessels in its neighbourhood. Even before the tubes are pressed upon, their epithelium becomes at first increased in quantity, and then fatty.

As further depositions occur, so the tubes suffer from greater pressure, the epithelium cells burst, the oil they contained coalesces, and as the continuity of the tube is destroyed by any irregularity of pressure, so does this oil collect, until the track of formerly healthy tubes, is distinguished by a linear series of refractile lacunæ, consisting of basement membrane containing oil.

Changes occur sooner or later in the tuberculous deposit, changes which are not necessarily produced by surrounding inflammatory action.

Softening or calcareous degeneration of the deposit may happen. That variety of softening which is independent of inflammatory action in the tissues around the tuberculous mass, commences in the centre, and appears to be caused by purely physical agencies. For, as a tuberculous mass increases by deposition upon its exterior, so, as such increase takes place, the centre of the original deposit becomes further removed from the influence of the circulation or of nutrition, it becomes more and more extra-vascular. The temperature of the surrounding parts, which are, moreover, always more or less moist, tends greatly to produce changes in the cohesion of the plasma, in which the cells of the centre of the tuberculous mass are imbedded; softening and a greater amount of fluidity of the plasma, or blastema, as it should rather be called, first occurs, and then the cells burst, from the effects of endosmosis and exosmosis.

Either the rest of the tuberculous mass may become softened by the influence of this decomposed cell-growth, and inflammatory action may be induced in the surrounding parts, or the softened blastema, and the cell contents may lose all vitality and degenerate into cholesterine, ammoniaco-magnesian phosphate, carbonate and

phosphate of lime and oil globules, in other words, they may undergo calcareous degeneration.

Tubercle is never transformed into pus, whose presence, near to or in contact with softening tubercle, is attributable to inflammatory action in the neighbouring tissues. Subsequently to the softening, the parts of the kidney in the immediate neighbourhood are destroyed by inflammation, abscesses are formed, which generally burst into the pelvis of the organ; they have been known to burst into the colon, and to open externally.

It is somewhat remarkable, that in the 5th Case, the tubes were compressed by the tubercular deposit, but did not contain fatty epithelium; the rapid progress of the deposit, of which there was plenty of evidence, probably affected the tubes before the nutrition of their epithelium could be interfered with.

The following is a summary of the appearances presented by the tubercular deposit in the cases here recorded.

Tubercle in its early stage, presented itself either as a more or less globular yellow cheesy mass, or as a small grey and semi-transparent body, merging occasionally into the first variety at the circumference. There were no instances of that alteration in the centre of the grey tubercles, so frequently met with in the lungs, nor was there an instance of tubercular infiltration.

The grey variety is much denser than the yellow, but both contain peculiar non-nucleated cells before they become softened or degenerate.

These cells form the bulk of the yellow and the smallest portion of the grey variety; the intercellular substance, on the contrary, constitutes by far the greatest part of the grey and but a small portion of the yellow deposit.

The intercellular structure is very dense, homogeneous, and transparent in grey and soft, and very granular in yellow tubercle. So that the yellow variety of tubercle consists of a number of non-nucleated cells, held together by a soft and rather scanty granular cytoblastema; whilst the grey variety is made up of a mass of dense homogeneous semi-transparent structure, containing but few non-nucleated cells.

These non-nucleated cells are characteristic of tubercle, and are evolved from the cytoblastema deposited by the capillary blood-vessels during some peculiar perversion of their function. They

consist of a tolerably dense wall membrane, enclosing a fluid which contains a greater or less number of refractile granules. Acetic acid does not influence the cell-wall, but it renders other granules evident in young tubercle cells.

The special cells of tubercle are never nucleated; cells with nuclei are, however, sometimes developed in the cytoblastema of tubercle, such was the case in more than one of the cases described in this Essay. The special cells vary in size; and this variation, and the occasional presence of nucleated cells, must be accounted for, by some irregularity in the power of cell development pertaining to the cytoblastema, and we can readily imagine that such deviation is very possible in so low a form of cell-structure as tubercle.

The recently-formed tubercle cell is globular, and its outline dark and circular, hence the refractility.

The cells are readily acted on by water, which passes through the cell-wall and mixes with the contents; after the admixture, the granules in the cells are seen to take on molecular motion, a phenomenon not observed before a thin fluid was added to the denser cell contents. As the tubercle cell matures, so its shape becomes more ovoid, and its outline irregular. It is in this form that they are generally presented to our notice; the granules within them are very distinct, and the cell is hardly at all influenced by water. They are best seen by using a good $\frac{1}{8}$th-inch focus glass, aided by the achromatic condenser, and it would be as well if, in the differential examination of tubercle, one high power alone were used. Pus, pyoid cells, compound granule cells, and other products of disordered nutrition, nuclei of epithelium, and the usual histologic elements of the affected part, can hardly be confounded with tubercle cells if the same microscopic power be used throughout the examination.

The life of a tubercle cell is a short one; on the first symptom of a change of consistence in the whole mass, the cells burst and their contents are set free; the granules appear not to undergo a change, but the fluid which held them in mechanical suspension during the life of the cell, suffers decomposition; after it escapes from the cell-wall it is resolved into principles nearly allied to the inorganic kingdom, into oil, cholesterin and various salts, and either becomes mixed with the products of inflammation of the surrounding

tissues, induced by its presence, or by losing its more fluid parts, becomes a dense calcareous mass.

That tubercle can be distinguished by any special structure may well be doubted, for the descriptions and drawings of its minute anatomy seem to vary with each author. Gulliver, Vogel, and Lebert draw cells of the most opposite character, as those peculiar to tubercle.

In Phillips's excellent work on scrofula there are drawings of tubercle by Gulliver and Lebert, and the dissimilarity of their views, apparently contradicts the notion of there being a special tubercle cell; but it is very evident to those who have interested themselves about the subject, that these great histologists have described the adventitious product at different stages of its existence.

Lebert's drawing represents tubercle in its first stage; the cells are non-nucleated, and have lost their globular, but have hardly arrived at their ovoid, form. The artist has made the granules to appear more superficial than they really are, indeed it is difficult to say whether they are outside or within the cell-wall.

Gulliver's plate represents broken down tubercle; the special cells have burst, their contents have been set free; his view really represents contents of tubercle cells, debris of cells, epithelium scales from some bronchi in the neighbourhood, and oil globules.

It will be seen, in the plates appended to this Essay, that the description I have given of the special cell of tubercle agrees mainly with that of Lebert, whose work on scrofulous and tuberculous diseases has lately been couronné by the French Academy.

I have before mentioned that the life of the special cells of tubercle is short, and that they must be sought before softening or calcareous degeneration occur, or their existence may well be doubted.

There is great room for speculation as to the causes of the deposition of tubercle. Unfortunately the facts upon which we are to build a theory are few, and reasoning by analogy, a poor method of argument in pathology, is constantly used. A theory of the ultimate causes of tubercle must account for the deposition from blood-vessels of a cytoblastema, and for the production of peculiar cells in this cytoblastema. The favourite theory of the day is, that there is a poison in the blood which tends to the elimination of

tubercle, in the same manner as other poisons tend to the elimination of morbid products. According to this theory, the presence of tubercles is caused by a "natural tendency in the living body to get rid of matters which would prove injurious if retained." There must be a relation between the amount of tubercular deposition and the intensity or amount of the peculiar poison.

Small enough must be the amount of poison which is to account for a single spot of tubercle, such as is frequently met with, in the lungs of aged subjects who have died from diseases evidently non-tubercular. Contrasted strangely with this paucity, is the fact that tuberculous deposition occurs within a very short time, and to an enormous extent, in some subjects who die not from the effects of the softening and consequent destructive tendency of tubercle, but from its mechanical influence. The lungs are occasionally found so affected by an enormous deposit of miliary tubercle as to be incapable of that resiliency which is necessary to the carrying out of their functions.

It is evident that, according to the theory now in vogue, the production of tubercle, and its decadence and influence upon the tissues around it, are caused by a vis medicatrix, which thus gets rid of the poison, and too often of the sufferer at the same time.

The constant deposition of new tubercle, which occurs during the process of elimination of that which was deposited previously, shows that a depressed state of the nutrition of the body, favours the production of this adventitious structure.

Mr. Simon's experiments have proved that tubercle can be produced by those agencies which tend to depress the state of the powers of nutrition, and it is notorious that we can frequently trace the origin of phthisis, to an attack of influenza, a severe cold, typhus fever, &c., to diseases which have a depressing effect upon the vital powers.

The advocates of the theory which hints at a special blood-poison as the remote cause of the development of tubercle, very reasonably insist that when the powers of life are low, the body is more liable to absorb morbid entities. A man in health may live for a time without inconvenience in a very malarious district, but subject him to depressing influences and he has an attack of ague forthwith.

It may be advanced that we have no right to attribute the development of tubercle to the presence of a morbid poison in the

blood, for it has never been isolated or even detected by chemical reagents; we must bear in mind, however, that an assertion may still be true, although it is not proveable by demonstration, and that we have a right to argue from probabilities and analogies.

It has not been advocated that the poison of tubercle is received into the body from without, and we have many examples of morbid products being developed within the system from some perversion of the general nutrition. No one will feel disposed to contradict the fact of there being a special poison of syphilis or of hydrophobia, or of glanders, yet the two last diseases are blood diseases, which arise without inoculation, in fact, spontaneously, and which are at the same time capable of transmission.

The poison of syphilis must have arisen within the system of the first sufferer. We have, then, an argument which renders it probable, that under certain depressed and perverted states of the nutrition of the system generally, that may be generated within the body which determines the development of tubercle. We infer with equal probability that all forms of carcinoma are produced in an analogous manner, but we have no knowledge of the cause which determines the endogenous cell-growth by which they are characterized.

EXPLANATION OF PLATES.

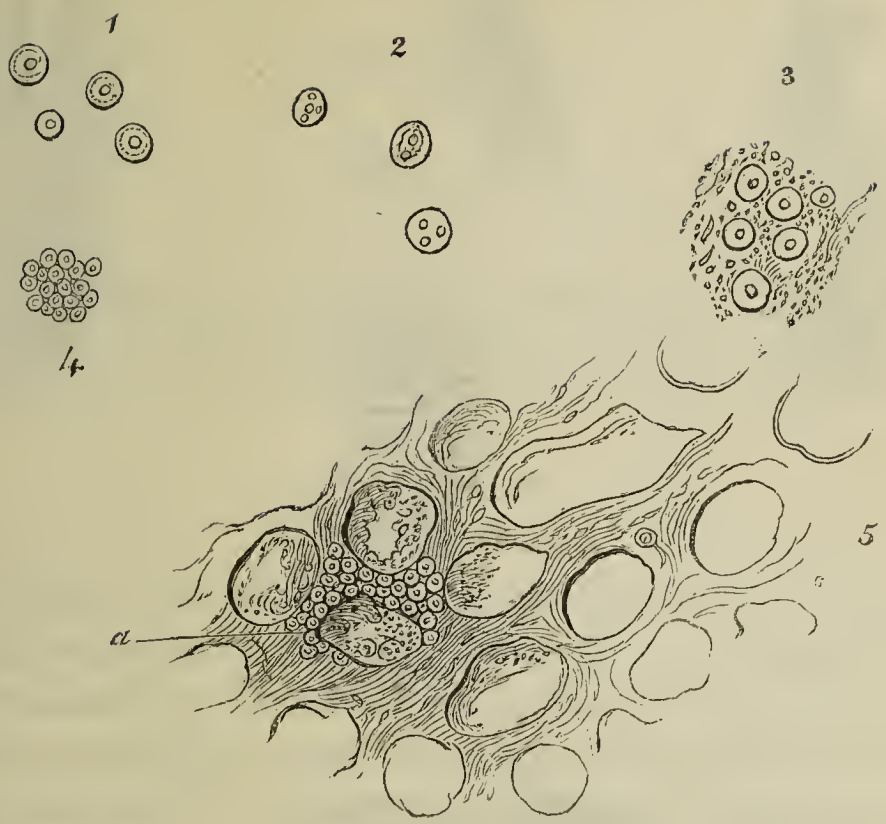
CASE I.—1. Tubercle cells, recent, and in the earliest stage. 2. Tubercle cells to which acetic acid has been added. 3. Tubercle cells surrounded by a soft granular cytoblastema. (Mag., 600 diameters.) 4. A mass of tubercle cells, not so highly magnified as the other specimens. 5. A transverse section of the matrix of the kidney, showing a mass of tubercle *(a)* replacing a portion of the intertubular fibrous tissue.

CASE II.—*A*. Tubercle cells resembling those of Case 1. *B*. Tubercle cells more fully developed than those at *A*. *C*. Small granular cells, nuclei of some fibres of the matrix of the kidney near the tubercular deposit. *D*. The smaller granules are those of which the bulk of the cytoblastema surrounding the tubercle cells principally consisted; they are of the same size as those seen within the cells. The larger globules are of oil, are soluble in sulphuric ether, thus differing from the smaller kind. *E*. Cells with ill-developed nuclei. In two of these cells the nucleus has separated into two portions, and one cell appears about to undergo fissiparous division. *F*. Fibres of the matrix, with granular nuclei, from the neighbourhood of a tubercular deposit. (Mag., 600 diam.)

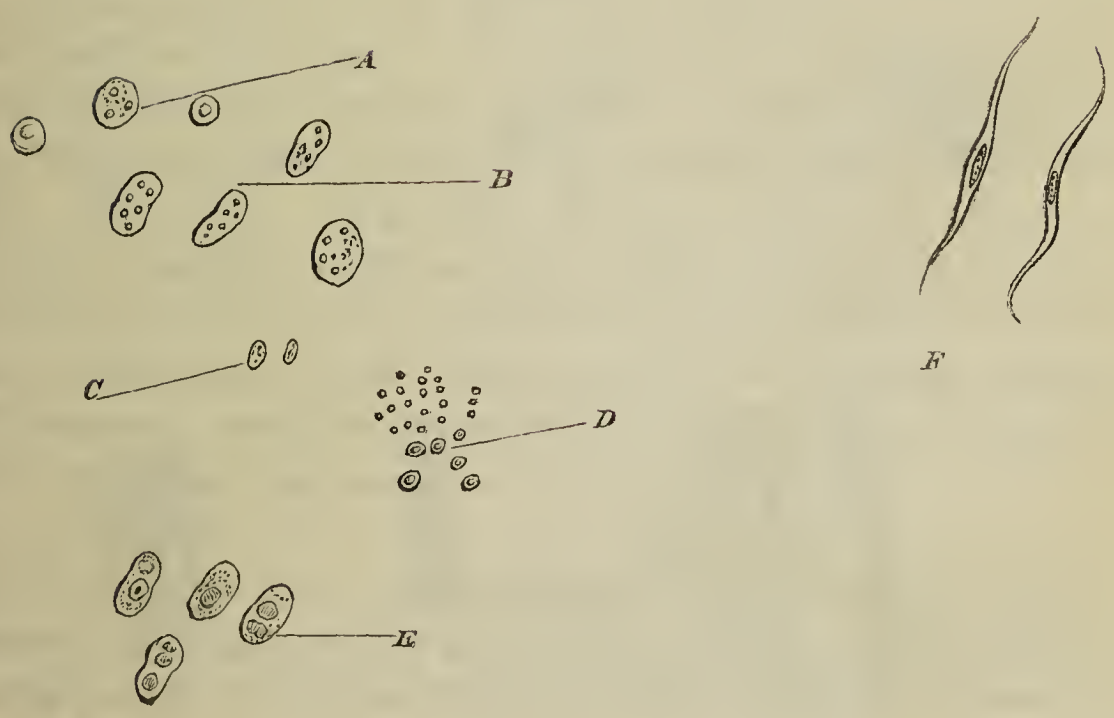
CASE III.—1. A portion of an uriniferous tube near to, but not in contact with, a tuberculous deposit. It is crammed with epithelium. 2. A portion of an uriniferous tube in contact with the edge of a tuberculous deposit. Epithelium fatty. 3. An uriniferous tube influenced by the dense amorphous stroma of a grey tubercular mass. Its caliber is encroached on irregularly; below it is obliterated. The tube, which is much narrowed, contains oil, the result of the coalescence of the fat globules of the epithelium with which the tube before it was surrounded by the dense tubercle, was crammed. 4. The remains of two parallel uriniferous tubes; the caliber of both is obliterated in several places; they are surrounded by a dense mass of tubercle, and contain oil. 5. The course of several uriniferous tubes through a dense semi-transparent tubercle, which involved the whole of one of the mammillary processes. *a*. Mucous membrane of mammillary process. *b*. Two parallel tubes much compressed and surrounded by the adventitious deposit. *c*. Portions of tubes suffering from irregular compression. Each linear series represents the track of a formerly healthy tube.

CASE V.—*(A)* 1. A large squamoid epithelium cell from the mucous membrane of the pelvis of the kidney; it contains many fat globules, and was only separated from a mass of tubercle by the basement membrane. 2. Tubercle cells from that part of the deposit nearest the healthy tissue of the kidney. (Mag., 600 diameters.) *(B)* 1. Uriniferous tubes within, and compressed by tubercle. 2. Some more highly magnified; the epithelial lining is just perceptible. 3. A healthy tube uncompressed. (Mag., 250 diameters.)

CASE I.



CASE II.



CASE III.

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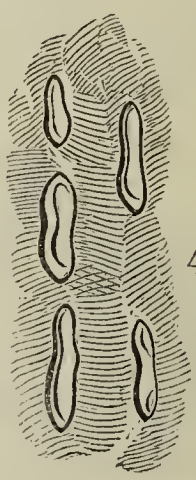

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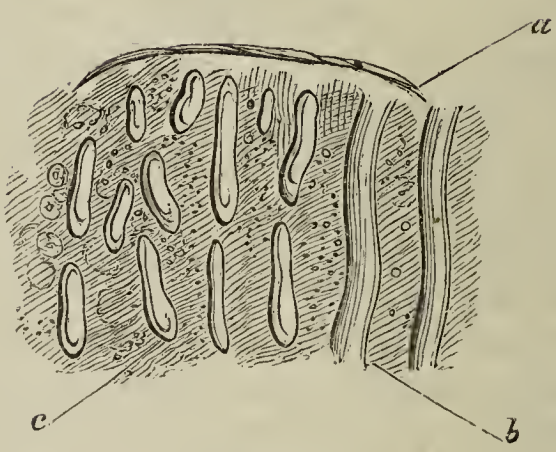

CASE V.

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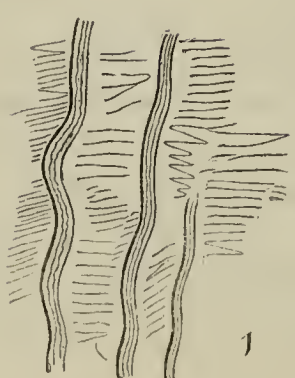

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B

APPENDIX.

A DESCRIPTION OF, AND REMARKS UPON, SOME CASES OF CYSTIC DISEASE OF THE KIDNEY.

The first case of cystic disease occurred in the Case No. 3. The cortex and medullary cones (pyramids) which corresponded to the diseased mammillary processes were the seat of numerous cysts. No cysts were found in those medullary cones whose mammillary processes were healthy. The cysts were small, varying in size from a pin's-head to the size of a mustard seed, and contained a brown viscid fluid, in which oil, cholesterin, and the debris of epithelium cells were found. Nitric acid produced crystals of nitrate of urea, when it was added to the fluid and suffered to evaporate. Sections of the uriniferous tubes in the neighbourhood of the cysts showed them to be greatly dilated. The area of the meshes of the fibrous matrix was much larger than usual, and the microscope made small cysts which were invisible to the naked eye very evident. There was always a greater or less amount of condensation of the fibrous matrix around these cysts. The dilated tubes were lined with a very thin and scanty layer of epithelium. The smaller cysts were lined with epithelium, which exactly resembled that of the dilated tubes. The larger cysts were lined in places by epithelium, generally speaking in spots near to capillary vessels, whose delicate permanent nuclei could be well seen. These capillaries were only found in the largest cysts. The cysts were not invariably globular, but frequently ovoid, and occasionally constricted at one spot, and more or less flask-shaped.

Case 2.—*(See Case 4 of the Essay.)*—Some of the mammillary processes were the seat of tubercular deposit. In the affected processes some uriniferous tubes were obliterated, and between the

obliterations and the malpighian ends of the tubes, a series of dilatations existed. The dilatations were seen apparently wherever there had been a turn in the tube, or between two meshes of the dense fibrous matrix.

A low microscopic power distinguished these rows of dilated portions of tubes, until they became confused and less regularly parallel in the cortex; here, however, several small cysts existed, which contained a reddish-yellow thick geletinous fluid, in which cholesterin and the debris of epithelium cells could be traced.

Case 3.—*See Case* 5 *of Essay.*—Both kidneys contained cysts varying in size from that of a mustard-seed to that of a pigeon's-egg; some of the larger cysts had been opened by destructive ulceration. Nearly all the medullary cones of these kidneys were diseased; the tubercular deposits had obliterated many of the uriniferous tubes as they came within its influence, but as they became more distant they suffered occasional bulgings, and as they passed on to the cortex, were formed into a series of microscopic cysts.

Small cysts and dilated tubes could readily be found in all parts of the cortex; the area of the meshes of the matrix was seen to be much increased when the tubes were washed out. The cysts contained a thick tenacious reddish fluid, in which phosphates, oil, cholesterin, and epithelium cells were found. The fluid yielded nitrate of urea on the addition of nitric acid.

The epithelium of the cysts was scanty; their wall consisted of more or less dense white fibrous tissue, numerous capillaries of the smallest size, ramified between the fibrous tissue and what appeared to be a basement membrane. Ovoid masses of nucleated epithelium existed near the capillaries, but the greater part of the cyst wall was destitute of cell covering.

Acetic acid rendered the appearance of the cyst wall much more distinct, dissolved the fibrous tissue, and made the nuclei of the epithelium and the walls of the capillaries much more distinct. (*See Wood-cut viii.*) 1. *A.* Capillary vessel. *B.* Patch of epithelium after the addition of acetic acid. 2. *a.* Epithelium cells as seen floating in the fluid of the cyst. *b.* Crystals of phosphate from the fluid (neutral phosphate of ammonia and magnesia.)

Case 4.—A patient of Mr. Clark's, of Colchester, died of hæmaturia. We found the kidneys highly vascular, the pelvic mucous membrane intensely injected, and the cavity filled with blood and urine. There were tuberculous masses in both kidneys, in all parts of them, and beneath the pelvic membrane. In either kidney there was an ulcerating surface evidently produced by the destructive influence of tubercle, and comprehending one or more mammillary processes. In one organ in a situation corresponding to the direction of the tubes of a pyramid, in which there was a large mass of tubercle, there was a good-sized cyst, which had all the characters of those in the last case. The tubes were dilated in the neighbourhood of the cyst, and constricted or obliterated near the tubercular deposition.

Case 5.—An octogenarian had some of the tubes of two or three of the mammillary processes blocked up with crystalline deposit. The tubes were dilated immediately above the deposition, and there were three cysts in that part of the kidney which corresponded to the course taken by these tubes.

One of the cysts was flask-shaped, a second was small, and contained the remains of a malpighian tuft.

Case 6—(Of which there is a lithograph appended to this paper), occurred in a young woman who died from active congestion of the brain. She never had any symptoms of renal disease, but died very suddenly. Cysts of all sizes and in great numbers were found in one kidney, and but a few small ones in the other. Dilated tubes and microscopic cysts were found, but I could discover no cause for the dilatation. The pyramids and mammillary processes were healthy, there was no adventitious product to be found. I have always been disposed to imagine that this woman suffered, probably after scarlet fever, or may be at some other time, from some form of desquamative nephritis, by which numerous tubes were blocked up for a time with epithelium, and were necessarily exposed to a dilating force above the obstacle to the passage of the urine.

In all the cases except the last, there were obstacles to the passage of urine through certain uriniferous tubes; and behind, or rather

between the malpighian tuft and the obstruction, the tubes were invariably dilated, sometimes to such a degree that they seriously affected the dimensions of the meshes of the fibrous matrix. *(See Wood-cut explanatory of the first stage of cystic disease.)*

It would appear that this dilatation cannot go on above a certain point, for the continuity of the dilated tube is endangered by the contact and pressure of others, and by the unyielding nature of the matrix, so that, after a time, microscopic cysts, in more or less linear series, are found in the place of dilated tubes.

These small cysts could be separated from the surrounding matrix, and, when subjected to careful compression, were found to contain epithelium of a smaller kind and more generally scanty than that of the dilated tubes.

It will be remembered that the epithelium of the dilated tubes was more scanty and of a smaller kind than that of the healthy tubes.

We cannot account for the dilatation and consequent cyst formation, by the effects of hydrostatic pressure alone, for the structures of the uriniferous tubes are of an unyielding nature. The force produced by accumulation of secretion may, however, act as a stimulus to the nutrition of the tubes, which then grow slowly, increase in caliber, and, with respect to healthy tubes, are more or less dilated.

Owing to unequal pressure or to the tortuous course, or to both, the continuity of a dilated tube is endangered; the dilatation increases above and below any constriction, and cyst upon cyst is formed; that is to say, the walls of the tube unite at one or more points. The cyst once formed has a tendency to increase in size; many of the principles usually eliminated by the kidney are found within them, besides a greater or less amount of epithelial growth. As they become larger, they have special blood-vessels devoted to them, and lose their epithelium, that is to say, epithelium is found no longer over the whole internal surface of the cyst, but only in certain patches, which are generally very close to the freshly developed capillaries. Phosphates, cholesterin, oil, and the remnants of malpighian tufts, are occasionally found in the cysts. We may with a degree of truth explain the increase of dimension of a cyst as an abortive attempt on Nature's part to eliminate the usual urinary secretion.

The pressure of the increased secretion acts as a distending force,

and stimulates the nutritive processes of the cyst-wall, which may increase in dimension to a very considerable extent. Cyst formation appears to occur without any inflammatory symptoms, and, as far as I have been able to make out, never is produced in unhealthy tubes.

APPENDIX.

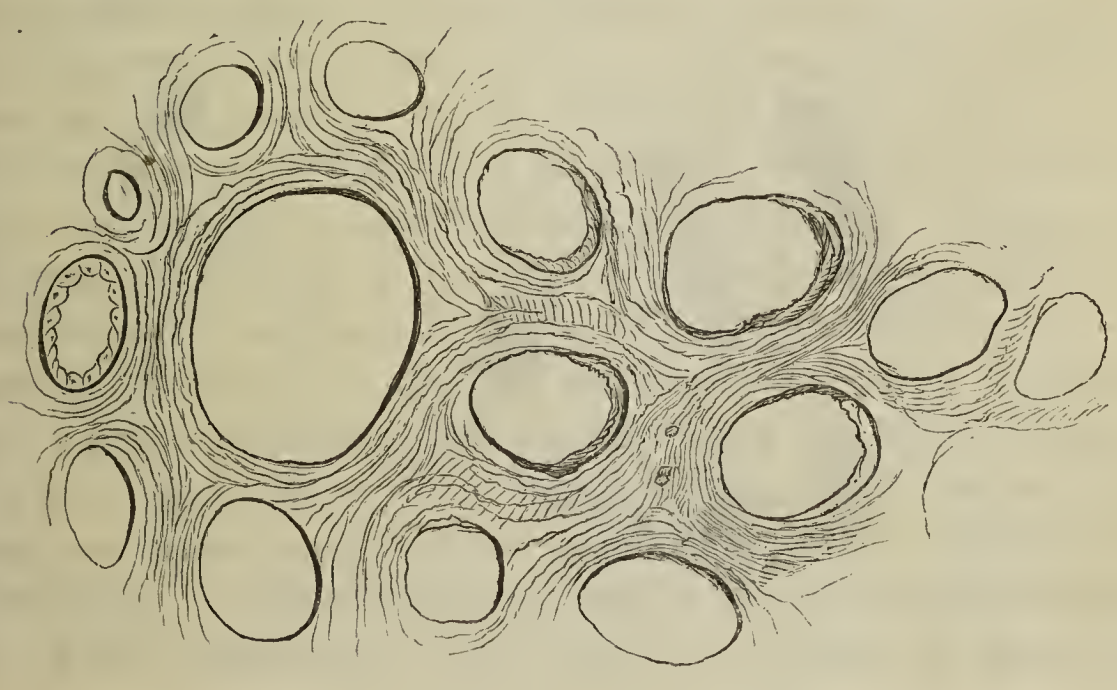
Lithograph.—A kidney, enlarged, and affected with cystic disease.

Cut I.—Matrix of a healthy kidney, a tranverse section, the tubes being washed out. The largest space was once filled by a malpighian body. (Magnitude, 600 diameters.)

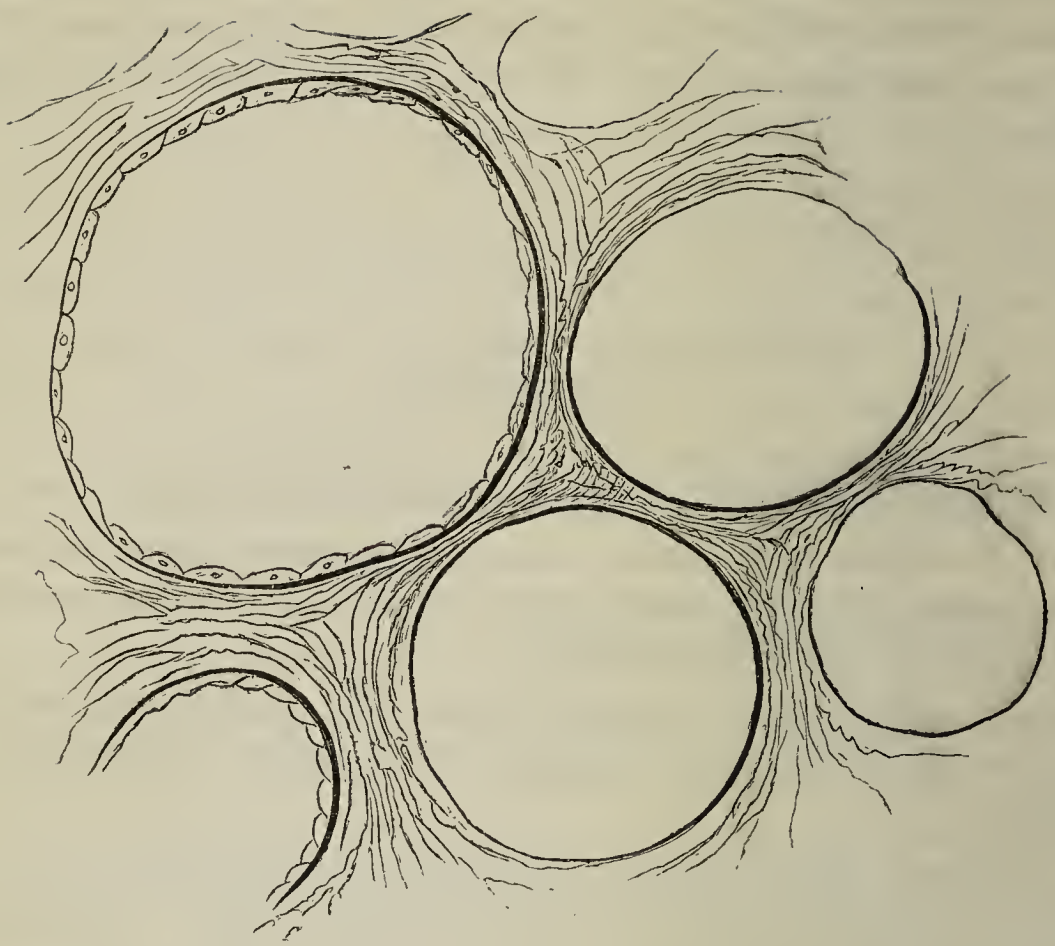
Cut II.—Showing how the matrix is encroached on by the dilatation of the tubes during the earlier stages of cystic disease. (Magnitude, 600 diameters.)

Cut III.—1. A portion of the wall of a very large and thin cyst. The view is of the internal surface; acetic acid has been added: two capillary vessels, with their permanent nuclei, are distinctly seen. The whole of the surface is not covered with epithelium; patches of it, in the immediate neighbourhood of the blood-vessels, alone exist. 2 *a*. Epithelium cells from the internal surface of a small cyst. *b*. Phosphatic crystals from the fluid of a cyst.

CUT I.



CUT II.



CUT III.

REPORT OF THE

MEDICAL AND SURGICAL CASES

TREATED IN THE WARDS OF THE

BRISTOL INFIRMARY DURING THE YEARS 1848 AND 1849.

BY HENRY AUGUSTUS HORE, HOUSE SURGEON.

The following Report of the Medical and Surgical Cases treated in the wards of the Bristol Infirmary during the past two years, was drawn up for my own private information and use; it is now brought before the profession at the suggestion of friends to whose judgment I felt bound to defer, and through the courtesy of the Council of the Provincial Association, has found a place in their *Transactions*.

The Bristol Infirmary, the largest and oldest provincial hospital in England, was instituted in 1735. It contains 240 beds, and in the two years to which this Report refers 4803 persons were treated as in-patients, and 22,832 as out-patients.

Of the advantages of the numerical classification over every other I need say nothing. The significant remarks of Gavarret, in his "Principles of Medical Statistics," that "the *sometimes* of the cautious is the *often* of the sanguine, the *always* of the empiric, and the *never* of the sceptic; but the numbers 1, 10, 100, 1000, have but one meaning to all mankind," speaks more for its adoption than any arguments I can adduce; and well indeed has it been observed by the accomplished physician who delivered the Retrospective Address at the seventh Anniversary Meeting of the Association at Liverpool, in 1839, "that those who undertake to augment the stores of medical science by numerical researches incur a degree of responsibility far surpassing that of the observers, who give the results of their experience in general terms. The latter we receive with various qualifications and deductions, as probabilities, or approximations to truth. We allow something for the mental constitution of the writer; something for his use of

language; something for his age, and a good deal for the amount of his experience; and, above all, we view what he tells us as subject to the testing of our own investigations. But statements which come before us unarrayed in the pomp of words, neither pointed by antithesis, nor embellished by tropes; not brightened by the false light of fancy, nor warm with the glow of enthusiasm or controversy, but standing in bare bleak columns and tables apparently in the very nakedness of truth, are received in a very different spirit. However opposed to our former opinions, there seems to be no appeal from them; there is no room for question or doubt, and we submit to them, not as to dogmas, but as to principles of the exact sciences."

I am deeply sensible of the responsibility mentioned in the foregoing extract, and only regret that the Report is not so *perfect* as I could wish. Its accuracy, however, I believe to be unimpeachable. The labour and application necessary to collect, arrange, and analyze the materials of which it is composed, have certainly made a considerable demand upon my time; but I have been cheered by the hope that the officials of other provincial hospitals will follow the example, and that in time we may have such a mass of valuable statistical information collected as to render us less dependent upon our continental brethren than we have hitherto been. The long-continued and conjoint labours of many would furnish an ample store of facts, and from these general principles might be deduced, highly advantageous to the profession at large; but to render labours of this kind of real practical utility, it would be necessary that they should *all* be brought under the supervision of two or three competent individuals, who could analyze and prepare from them a condensed general report, embracing the more interesting portions, or those most likely to be useful to the medical public. I trust in my reports of future years to have an opportunity of recording in general terms the treatment pursued in some of the more important diseases. I have not done so on the present occasion, fearing that it would render the report too lengthy, and thereby deter other hospitals from undertaking what would appear to be so laborious a task. I may be allowed to observe, that before adopting the arrangement observed in this Report several other plans were tried, none of which appeared to me so comprehensive and easily carried out.

GENERAL TABLE OF RESULTS OF MEDICAL CASES.

	PRIMARY DIVISIONS.	1848. Cured.	1848. Made Out-patients.	1848. Relieved, Incurable, &c.	1848. Died.	1848. Total.	1848. Per centage of Deaths.	1849. Cured.	1849. Made Out-patients.	1849. Relieved, Incurable, &c.	1849. Died.	1849. Total.	1849. Per centage of Deaths.
	Diseases of the												
A.	Brain and Nervous System	36	45	21	13	115	11.30	33	58	14	15	120	12.50
B.	Lungs and Appendages.....	87	88	15	41	231	17.75	59	96	20	35	210	16.66
C.	Circulatory System.....	13	7	2	9	41	21.95	13	22	7	14	56	25.0
D.	Digestive System	109	69	13	15	206	7.28	87	68	14	8	177	4.52
E.	Integuments	20	25	3	...	48	...	29	24	3	...	56	...
F.	Genito-Urinary System	38	77	15	7	137	5.11	21	95	22	11	149	7.38
G.	Fibrous Tissues	128	73	6	3	210	1.43	99	78	11	...	188	...
H.	Fevers	160	25	...	9	194	4.66	119	22	3	7	151	4.63
* I.	Poisons	64	...	...	1	65	1.54	6	1	...	...	7	
	Total results	655	409	75	98	1247		466	464	94	90	1114	
	General per centage ...	52.53	33.60	6.01	7.86			41.83	41.65	18.50	8.7		

* See Note at bottom of Table I.

A.—DISEASES OF THE BRAIN AND NERVOUS SYSTEM.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Congestion and Inflammation of the Brain	11	6	2	5	24	20.8	10	14	2	9	35	26.31
Apoplexy	1	...	...	5	6	83.3	2	3	2	3	10	30.
Mania	...	...	1	...	1	...	...	...	...	...	...	...
Intoxication	2	...	...	...	2	...	2	...	...	...	2	...
Hypochondriasis	...	3	1	...	4	...	1	3	1	...	5	...
Paralysis	1	12	7	...	20	...	2	7	3	...	12	...
Delirium Tremens	1	...	...	1	2	50.	3	3	...	1	7	14.28
Convulsions	...	...	...	...	...	...	2	1	...	...	3	...
Epilepsy	2	9	5	...	16	...	1	5	4	...	10	...
Tetanus, idiopathic	1	...	...	...	1	...	1	...	...	...	1	...
Hysteria	8	8	...	...	16	...	4	9	1	...	14	...
Chorea	6	5	1	...	12	...	2	8	...	...	10	...
Neuralgia	2	2	...	...	4	...	1	3	...	...	4	...
Inflammation of Spinal Cord.....	1	...	4	2	7	28.57	1	2	2	2	7	28.57
Total results	36	45	21	13	115		32	58	15	15	120	
General per centage.....	31.31	39.13	18.26	11.30			27.50	48.33	11.66	12.50		

B.—DISEASES OF THE LUNGS AND APPENDAGES.

SUB-DIVISIONS.	1848. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	1849. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Asphyxia	2	...	...	...	2	...	...	...	...	...	...	...
Laryngitis	1	1	2	1	5	20.	2	...	1	...	3	...
Pleuritis	5	1	...	1	7	14.28	1	2	...	...	3	...
*Pleuropneumonia	32	26	2	8	68	11.76	26	27	2	5	60	8.33
*Bronchitis	29	31	1	...	61	...	27	37	2	3	69	4.34
*Phthisis	...	23	10	29	62	48.08	...	26	15	25	66	38.46
Influenza	15	3	...	...	18	...	2	...	...	...	2	...
Cancer of the Lungs	...	...	...	1	1	100.	...	...	...	2	2	100.
Hydrothorax and Anasarca, occurring in cases of Chronic Bronchitis and Phthisis	3	3	...	1	7	14.28	1	4	...	...	5	...
Total results	87	88	15	41	231		59	96	20	35	210	
General per centage	37.66	38.10	6.49	17.75			28.09	45.71	9.52	16.66		

* See Tables B 1 and B 2.

B 1.—SEXES, AGES, & DEATHS, in Decennial Periods, of PATIENTS ADMITTED with PLEUROPNEUMONIA, BRONCHITIS, & PHTHISIS.

1848.		Under 10.		Died.		10 to 20.		Died.		20 to 30.		Died.		30 to 40.		Died.		40 to 50.		Died.		50 to 60.		Died.		60 and upwards.		Died.		Males.	Females.	Total Males and Females.	Died, Males.	Died, Females.	Total Died.	Per centage of Males.	Per centage of Females.	Per centage of Deaths in Malcs.	Per centage of Deaths in Females.	General per centage of Deaths.
DISEASE.		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F									
Pleuropneumonia...		1	1	1	–	6	6	–	–	18	10	2	–	6	5	–	–	6	–	1	–	4	3	2	1	2	–	1	–	43	25	68	7	1	8	63.2	36.8	16.3	4.	11.76
Bronchitis		2	1	–	–	5	6	–	–	6	8	–	–	4	7	–	–	3	3	–	–	5	8	–	–	1	2	–	–	26	35	61	–	–	–	42.6	57.4	–	–	–
Phthisis		1	–	–	–	5	–	3	–	22	19	7	5	6	2	5	2	1	1	1	1	2	1	2	1	1	1	1	1	38	24	62	19	10	29	61.1	38.8	50.	41.7	48.08
1849.	Pleuropneumonia	3	–	–	–	6	3	1	–	11	9	1	–	10	4	1	–	5	–	–	–	5	2	–	–	1	1	1	1	41	19	60	4	1	5	68.3	31.7	9.7	5.2	8.33
	Bronchitis	5	3	–	–	6	1	–	–	7	10	1	–	12	3	–	–	5	5	–	–	2	4	–	–	6	–	2	–	43	26	69	3	–	3	62.3	37.7	6.9	–	4.34
	Phthisis	–	1	–	1	8	6	2	2	22	9	9	2	10	4	4	1	2	–	1	–	2	1	1	1	1	–	1	–	45	21	66	18	7	25	68.2	31.8	40.	33.3	38.46

*B 2.—NUMBER OF PATIENTS ADMITTED IN EACH MONTH WITH PLEUROPNEUMONIA, BRONCHITIS, AND PHTHISIS.

DISEASE.	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.		Males.	Females.	Total.
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.			
1848.																											
Pleuropneumonia.....	4	2	6	3	2	1	4	2	8	4	4	1	1	2	2	1	3	–	5	4	2	1	3	2	44	23	67
Bronchitis	3	6	3	4	4	–	2	6	2	4	1	4	1	3	3	–	3	2	3	2	3	4	5	3	33	38	71
Phthisis	1	1	2	2	6	5	4	1	4	–	2	2	1	3	1	2	–	–	5	3	6	4	4	2	36	25	61
1849.																											
Pleuropneumonia.....	3	6	3	2	5	–	4	2	5	1	2	1	1	1	1	1	3	1	5	2	2	1	3	1	37	19	56
Bronchitis	3	3	3	1	6	1	1	4	3	5	4	3	4	1	1	3	2	1	3	–	5	2	7	4	42	28	70
Phthisis	4	3	7	2	4	2	2	1	4	1	4	3	5	1	2	3	2	4	7	2	4	2	3	–	48	24	72

* This Table may not correspond with the General Table which refers to the cases admitted and discharged.

C.—DISEASES OF THE CIRCULATORY SYSTEM.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Heart and Pericardium	3	11	1	4	19	21.05	3	9	4	5	21	23.8
Dropsy, from diseases of the Heart	2	...	1	1	4	25.	...	6	2	5	13	38.5
Cyanosis	...	1	...	...	1	...	...	...	...	...	...	...
Aneurisms	...	...	...	2	2	100.	...	...	...	2	2	100.
Hæmatemesis	1	...	...	1	2	50.	2	1	...	...	3	...
*Epistaxis	...	...	...	1	1	100.	...	...	...	...	...	...
Anæmia	1	2	...		3	...	...	...	...	...	...	...
Purpura Hæmorrhagica	4	3	...	...	7	...	2	6	1	1	10	10.
Purpura Nautica	2	...	...	...	2	...	6	...	...	...	6	...
†Phlebitis	...	...	...	...		...	...	...	...	1	1	100.
Total results	13	17	2	9	41		13	22	7	14	56	
General per centage ...	31.71	41.46	4.88	21.95			23.21	39.28	12.50	25.0		

* This case occurred in a prostitute of intemperate habits. She was stated to have lost at different times five pints of blood before admission. The hæmorrhage was stopped immediately, by plugging the nares. She died several days after admission, never having regained her strength, without any additional perceptible cause.

† Occurred in a patient suffering from acute inflammation of the hip-joint, who was admitted with supposed rheumatism. He was too ill to be removed to a surgical ward; hence the case is enumerated in this Table.

D.—DISEASES OF THE DIGESTIVE SYSTEM.

SUB-DIVISIONS.	1848. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	1849. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Inflammation of the Gums and Mouth	...	...	...	...	...	...	4	1	...	...	5	...
*Cynanche Tonsillaris	11	5	...	2	18	11.11	21	7	2	...	30	...
Cynanche Parotidœa	2	1	...	...	3	...	...	...	...	...	...	...
Dyspepsia, &c.	49	30	8	...	87	...	14	20	6	...	40	...
Gastritis	7	2	...	...	9	...	4	2	1	...	7	...
Cancer of Stomach	...	2	...	1	3	33.33	...	...	...	...	...	...
†Peritonitis and Enteritis	6	6	...	1	13	7.69	6	2	1	2	11	18.2
Diarrhœa and Dysentery	9	4	3	4	20	20.	20	6	2	3	31	9.7
Strangulation of small intestine by a band extending from the Umbilicus to the Mesentery	...	...	...	...	...	...	...	...	...	1	1	100.
Constipation	2	...	...	...	2	...	4	1	...	...	5	...
Colic	7	2	...	...	9	...	4	9	...	...	13	...
Congestion and Inflammation of the Liver	15	10	...	3	28	10.7	10	13	...	...	23	...
Cancer of the Liver	...	1	1	1	3	33.33	...	1	...	1	2	50.
Ascites, from disease of Liver	1	5	1	3	10	30.	...	4	2	...	6	...
Ascites, from disease of Pancreas	...	...	...	...	...	...	...	...	...	1	1	100.
Disease of the Pancreas	...	1	...	...	1	...	...	...	...	...	...	...
Tabes Mesenterica	...	...	...	...	...	...	...	2	...	...	2	...
Total results	109	69	13	15	206		87	68	14	8	177	
Total per centage	52.91	33.50	6.31	7.28			49.15	38.42	7.91	4.52		

* Deaths caused by extension down the larynx.

† Deaths occurred in cases of tubercular peritonitis.

E.—DISEASES OF THE INTEGUMENTS.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Erythema	10	6	1	...	17	...	12	4	...	...	16	...
Vesicular Eruptions	5	9	1	...	15	...	11	9	...	...	20	...
Squamous Eruptions	...	4	...	...	4	...	2	4	1	...	7	...
Pustular Eruptions	...	...	...	...	...	...	2	...	...	...	2	...
Tubercular Eruptions	...	...	...	...	...	...	...	...	1	...	1	...
Venereal Eruptions	5	6	1	...	12	...	2	7	1	...	10	...
Total results	20	25	3	...	48		29	24	3	...	56	
Total per centage	41.7	52.08	6.2	...			51.78	42.86	5.36	...		

F.—DISEASES OF THE GENITO-URINARY SYSTEM.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Albuminuria	...	9	1	4	14	28.6	...	1	...	10	11	90.9
Diabetes	...	1	3	1	5	20.	...	1	...	...	1	...
Nephritis	13	1	1	...	15	...	4	6	3	...	13	...
Hæmaturia	1	...	...	...	1	...	...	...	...	...	...	...
Oxaluria	...	...	1	...	1	...	...	...	...	...	...	...
Diseases peculiar to Women:												
Chlorosis	7	30	...	...	37	...	4	34	3	...	41	...
Amenorrhœa	1	3	...	...	4	...	3	13	4	...	20	...
Dysmenorrhœa	7	13	3	...	23	...	6	9	2	...	17	...
Menorrhagia	5	4	1	...	10	...	...	3	...	...	3	...
Metritis	2	4	2	...	8	...	4	20	3	...	27	...
Malignant disease of Uterus	2	4	2	...	8	...	...	2	3	...	5	...
Ovarian Dropsy	...	8	1	1	10	10.	...	6	4	1	11	9.
Abscess of Ovary	...	...	...	1	1	100.	...	...	...	...	...	...
Total results	38	77	15	7	137		21	95	22	11	149	
Total per centage	27.74	56.20	10.95	5.11			14.09	63.76	14.76	7.38		

* G.—DISEASES OF THE FIBROUS TISSUES.

SUB-DIVISIONS.	1848.						1849					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Rheumatism, Acute	82	35	2	2	121	1.65	70	39	1	...	110	...
Rheumatism, Chronic	13	6	1	...	20	...	2	5	3	...	10	...
Rheumatism, Syphilitic	8	12	...	1	21	4.76	8	12	3	...	23	...
Periostitis	2	4	1	...	7	...	2	7	1	...	10	...
Lumbago	5	3	1	...	9	...	6	4	1	...	11	...
Sciatica	6	4	...	...	10	...	3	2	...	...	5	...
Lumbago and Sciatica	12	9	1	...	22	...	8	9	2	...	19	...
Total results	128	73	6	3	210		99	78	11	...	188	
Total per centage	60.95	34.76	2.86	1.43			52.66	41.49	5.85	...		

* See Tables G 1 and G 2.

G 1.—SEXES, AGES, & DEATHS, in Decennial Periods, of PATIENTS ADMITTED with ACUTE AND CHRONIC RHEUMATISM.

1848.	Under 10.		Died.		10 to 20.		Died.		20 to 30.		Died.		30 to 40.		Died.		40 to 50.		Died.		50 to 60.		Died.		60 and upwards.		Died.		Males.	Females.	Total Males and Females.	Died, Males.	Died, Females.	Total Died.	Per centage of Males.	Per centage of Females.	Per centage of Deaths in Males.	Per centage of Deaths in Females.	General per centage of Deaths.
DISEASE.	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F									
Acute and Chronic Rheumatism...	3	1	1	–	19	19	–	–	16	29	1	–	16	14	–	–	12	–	–	–	3	7	–	–	1	1	–	–	70	71	141	2	–	2	49.6	50.4	2.8	–	1.4
1849.																																							
Acute and Chronic Rheumatism...	1	–	–	–	11	21	–	–	21	21	–	–	14	9	–	–	7	5	–	–	7	–	–	–	2	1	–	–	63	57	120	–	–	–	52.5	47.5	–	–	–

*G 2.—NUMBER OF PATIENTS ADMITTED IN EACH MONTH WITH ACUTE AND CHRONIC RHEUMATISM.

DISEASE.	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.		Males.	Females.	Total.
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.			
1848.																											
Acute and Chronic Rheumatism ...	7	6	7	3	6	7	6	7	4	2	8	5	7	7	9	9	7	7	9	6	11	5	4	6	85	70	155
1849.																											
Acute and Chronic Rheumatism ...	4	6	6	2	2	5	8	2	6	8	5	6	11	6	7	5	6	2	5	10	11	4	7	6	81	62	143

* This Table may not correspond with the General Table which refers to the cases admitted and discharged.

H 1.—SEXES, AGES, AND DEATHS, IN DECENNIAL PERIODS, OF PATIENTS ADMITTED WITH FEVER AND FEBRICULA.

DISEASE.	Under 10.		Died.		10 to 20.		Died.		20 to 30.		Died.		30 to 40.		Died.		40 to 50.		Died.		50 to 60.		Died.		60 and upwards.		Died.		Males.	Females.	Total, Males and Females.	Died, Males.	Died, Females.	Total Died.	Per centage of Males.	Per centage of Females.	Per centage of Deaths in Males.	Per centage of Deaths in Females.	General per centage of Deaths.
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F										
1848.																																						
Fever	2	2	–	–	17	28	1	3	14	25	2	1	5	3	–	–	2	4	–	1	–	1	–	–	1	–	–	–	41	63	104	3	5	8	39.4	60.6	7.3	8.9	7.69
Febricula ...	2	4	–	–	15	8	–	–	3	14	–	–	2	1	–	–	1	–	–	–	–	–	–	–	–	1	–	–	23	28	51	–	–	–	45.09	54.9	–	–	–
1849.																																						
Fever	5	3	–	–	12	18	–	–	22	22	2	2	5	3	1	1	–	2	–	–	1	3	–	–	–	1	–	–	45	52	97	3	3	6	46.4	52.8	6.7	5.7	6.21
Febricula ...	–	1	–	–	1	10	–	–	3	9	–	–	–	2	–	–	1	2	–	–	–	1	–	–	–	–	–	–	5	25	30	–	–	–	16.7	83.3	–	–	–

* H.—FEVERS.

SUB-DIVISIONS.	1848. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	1849. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Continued, &c.	85	11	...	8	104	7.69	79	10	2	6	97	6.21
†Febricula	42	9	...	...	51	...	21	9	...	...	30	...
Intermittent	14	2	...	...	16	...	3	2	...	...	5	...
Scarlatina	2	...	...	...	2	...	1	...	...	...	1	...
Variola	3	...	...	...	3	...	1	...	...	...	1	...
‡Erysipelas	14	3	...	1	18	5.55	14	1	1	1	17	5.88
Total results	160	25	...	9	194		119	22	3	7	151	
Total per centage	82.66	12.98	...	4.66			78.81	14.57	1.99	4.63		

* See Tables H 1 and H 2.

† The term febricula is applied to cases which are evidently of the same species as fever, but from the age, constitution, class of patients, and other causes, do not run the usual course of severer cases of fever. The invasion, state of tongue, skin, and pulse, are the same in both; but the course is much shorter and the convalescence much more rapid in febriculæ. It would be wrong to dismiss these cases from the class of fevers, and it would also lead to improper deductions, by comparison of the results, if they were classified under the head of fever.

‡ Under this head are included only the idiopathic cases, those occurring in the surgical wards not being enumerated.

* H 2.—NUMBER OF PATIENTS ADMITTED IN EACH MONTH WITH FEVER AND FEBRICULA.

DISEASE.	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.		Males.	Females.	Total.
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.			
1848.																											
Fever	3	11	8	8	1	4	4	4	2	4	4	5	4	1	2	4	5	4	6	3	2	8	1	3	42	59	101
Febricula ...	1	1	4	4	4	2	5	2	4	3	1	1	5	3	1	5	1	8	2	4	2	6	2	1	32	40	72
1849.																											
Fever	3	5	4	3	3	5	4	1	2	4	7	3	2	6	10	5	4	4	4	6	6	3	4	3	53	48	101
Febricula ...	–	2	1	2	–	1	–	4	–	4	2	–	–	2	2	5	2	2	–	–	–	1	–	3	7	26	33

* This Table may not correspond with the General Table which refers to the cases admitted and discharged.

I.—POISONS.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Laudanum	2	...	...	...	2	...	3	...	...	...	3	...
Sulphuric Acid	1	...	...	...	1	...	...	...	...	...	...	...
Caustic Potass	...	...	...	...	...	...	1	...	...	...	1	...
Bichloride of Mercury	...	...	...	1	1	100.	...	...	...	...	...	...
Ammonia—Chloride of Mercury	...	...	...	...	...	...	1	...	...	...	1	...
Oxalic Acid	2	...	...	...	2	...	...	...	...	...	...	...
Sulphate of Copper	1	...	...	...	1	...	...	...	...	...	...	...
Acetate of Lead	...	...	...	...	...	...	...	1	...	...	1	...
Muscles	1	...	...	...	1	...	1	...	...	...	1	...
Cacumis Colocynthis	1	...	...	...	1	...	...	...	...	...	...	...
*Seeds of Jatropha Curcas	56	...	...	...	56	...	...	...	...	...	...	...
Total results	64	...	...	1	65		6	1	...	...	7	
General per centage	98.46	...	...	1.54			85.71	14.29	...	...		

* They resemble small beans, and are of the same order as the Croton Tiglium, and have at first a sweet taste, soon followed by a hot burning sensation. These seeds were accidently spilled in the streets, and picked up by some children, who, pleased with their taste and appearance, thought they were harmless, and ate them unsuspiciously; in many instances between fifteen and twenty were eaten by one person. The symptoms presented were, burning heat in the mouth, throat, and epigastrium, followed soon by purging, vomiting, great collapse, and, in some instances, cramps in the lower extremities. Only the most severe cases were admitted into the wards, more than fifty more were treated as out-patients.

NUMBER OF PATIENTS ADMITTED IN EACH MONTH.

	January.		February.		March.		April.		May.		June.		July.		August.		Sept.		October.		Nov.		Dec.		Males.	Females.	Total.	Percentage of Males.	Percentage of Females.
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.					
1848.	46	51	50	38	48	49	46	54	97	73	39	46	51	50	53	48	57	51	48	54	45	52	36	41	616	605	1221	50.4	49.6
1849.	44	63	36	44	41	45	40	42	50	65	37	49	43	39	50	57	45	50	45	59	47	50	44	47	522	610	1132	46.1	53.9

2 N

GENERAL TABLE OF RESULTS OF SURGICAL CASES.

	PRIMARY DIVISIONS.	1848. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	1849. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
	Injuries and Diseases of the												
A.	Brain and Nervous System	13	5	1	7	26	26.9	15	5	...	1	21	4.7
B.	Lungs and Appendages.....	1	3	...	...	4	...	10	1	1	5	17	20.
C.	Organs of Circulation.....	6	5	1	1	13	7.4	3	10	...	2	15	13.3
D.	Organs of Digestion	25	17	4	3	49	6.1	33	18	6	3	60	5.
E.	Integuments	219	179	18	20	436	4.5	192	177	27	21	417	5.04
F.	Lymphatic and Glandular Systems	15	18	3	2	38	5.2	19	16	2	...	37	...
G.	Genito-Urinary System	42	26	9	...	77	...	24	40	12	2	78	2.5
H.	Joints, &c.	116	81	25	4	226	1.8	117	114	28	3	262	1.2
I.	Eyes, Ears, and Nails	17	16	3	...	36	...	7	12	4	...	23	...
K.	Bones, injuries of	124	73	7	16	220	7.2	106	113	2	6	227	2.6
L.	Bones, diseases of	7	33	21	2	63	3.2	9	32	15	3	59	5.08
M.	Tumours	7	14	2	1	24	4.2	5	7	1	1	14	7.1
	Total results	592	470	94	56	1212		540	545	98	47	1230	
	General per centage ...	48.84	38.78	7.76	4.62			43.9	44.4	7.9	3.7		

A.—INJURIES AND DISEASES OF THE BRAIN AND NERVOUS SYSTEM.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Brain, concussion of	8	3	...	...	11	...	10	3	...	...	13	...
Brain, inflammation following injuries of the head	3	...	...	...	3	...	2	...	...	...	2	...
Deafness, following injuries of the head	...	1	...	...	1	...	...	...	...	...	...	...
Concussion of the Spine	2	...	...	...	2	...	3	1	...	...	4	...
Paralysis, following injuries of the Spine	...	1	1	...	2	...	...	...	...	...	...	...
Neuroma	...	...	...	...	...	...	...	1	...	...	1	...
Tetanus	...	...	...	4	4	100.	...	...	...	1	1	100.
Delirium Tremens	...	...	...	3	3	100.	...	...	...	...	...	...
Total results	13	5	1	7	26		15	5	...	1	21	
General per centage ...	50.	19.23	4.	27.			71.4	23.8	...	4.8		

B.—INJURIES AND DISEASES OF THE LUNGS AND APPENDAGES.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Larynx, Wounds of.....	...	...	...	...	...	...	1	...	...	3	4	75.
Larynx, Scalds of	...	...	...	...	...	...	3	...	...	1	4	25.
*Larynx, Foreign body in	...	...	...	...	...	...	1	...	...	1	2	50.
Pneumonia, following injuries of the Thorax	1	2	...	...	3	...	2	1	1	...	3	...
Asphyxia, from strangulation, immersion in water, &c.	...	1	...	...	1	...	3	...	...	...	3	...
Total results	1	3	...	...	4		10	1	1	5	16	
General per centage.....	25.	75.	...	...			58.7	5.8	5.8	29.4		

* The death occurred in a child who swallowed a piece of glass, which perforated the æsophagus, and became impacted in the trachea. Tracheotomy was performed, and the patient died the day after the operation.

C.—INJURIES AND DISEASES OF THE ORGANS OF CIRCULATION.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Wounds of Arteries	3	3	...	...	6	...	...	3	...	...	3	...
Aneurism	...	...	...	...	...	...	1	...	...	...	1	...
Phlebitis	2	...	...	...	2	...	1	1	...	...	2	...
*Veins, Rupture of	...	1	...	...	1	...	...	3	...	1	4	25.
Veins, Varicose	...	...	...	...	...	...	...	2	...	...	2	...
Epistaxis	1	...	...	...	1	...	1	...	...	...	1	...
Nævus	...	1	...	...	1	...	...	1	...	...	1	...
Gangrena Senilis	...	...	1	1	2	50.	...	...	...	1	1	100.
Total results	6	5	1	1	13		3	10	...	2	15	
General per centage	46.15	38.47	7.69	7.69			20.	66.6	...	13.3		

* The death occurred in a man, aged 50, who was admitted with hæmorrhage from the vena saphena interna, which was varicose throughout its entire extent; the leg was ulcered. Erysipelas supervened, from which he recovered. After the patient had been in the wards fourteen weeks, when the ulcer was *almost healed*, apoplexy suddenly came on, and he died seven hours after the commencement of the attack.

D.—INJURIES AND DISEASES OF THE ORGANS OF DIGESTION.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Wounds of the Mouth	...	...	...	...	...	...	1	1	...	...	2	...
Scalds of the Mouth and Throat	...	...	...	...	...	...	8	...	...	...	8	...
Alveolary Abscess	1	...	...	...	1	...	1	2	...	...	3	...
Malignant disease of the Mouth and Throat	...	3	...	...	3	...	...	...	...	...	...	...
Ranula	...	...	...	...	...	...	...	1	...	...	1	...
Hypertrophy of Tonsils	5	4	...	...	9	...	...	1	...	...	1	...
Disease of the Palate	...	...	1	...	1	...	...	...	...	...	...	...
Tumour of the Lip	...	...	...	...	...	...	2	...	...	...	2	...
Ulceration of the Lip	1	...	...	...	1	...	...	...	...	...	...	...
Hare Lip	1	...	...	...	1	...	3	...	3	...	6	...
Polypus Nasi	...	...	...	...	...	...	...	1	...	...	1	...
Hernia	12	1	...	3	16	18.7	13	...	...	2	15	13.3
Wound of the Abdomen	1	...	...	...	1	...	1	...	...	...	1	...
Fæcal Fistula	...	2	...	...	2	...	...	...	...	...	...	...
Rupture of the Liver	...	...	...	...	...	...	...	...	...	1	1	100.
Diseases of the Rectum :—												
Ulceration	...	...	1	...	1	...	1	...	...	...	1	...
Stricture	...	...	...	...	...	...	...	1	...	...	1	...
Fistula	4	6	2	...	12	...	2	10	1	...	13	...
Hæmorrhoids	...	1	...	...	1	...	1	1	2	...	4	...
Total results	25	17	4	3	49		33	18	6	3	60	
General per centage	50.	34.69	8.16	6.12			55.	30.	10.	5.		

Fractures of the Radius and Ulna,	simple	2	2	1	...	5	...	3	5	...	...	8	...
,, ,,	compound	...	...	...	...	...	...	...	1	...	...	1	...
,, ,,	compound, comminuted	...	1	...	...	1	...	...	1	...	...	1	...
,, ,,	bent	2	1	...	...	3	...	...	...	...	...	...	...
,, Hand & Fingers,	with laceration, &c.	1	9	2	...	12	...	2	8	...	...	10	...
,, Pelvis		...	...	...	1	1	100.	...	...	...	...	...	...
,, *Femur,	simple	18	1	...	1	20	5.	22	1	1	3	27	11.1
,, ,,	double	...	...	...	2	2	100.	1	1	...	...	2	...
,, ,,	compound	...	...	...	...	...	...	1	...	...	...	1	...
,, Patella,	simple	1	1	...	...	2	...	...	4	...	...	4	...
,, †,,	compound	...	...	...	1	1	100.	...	1	...	...	1	...
,, Fibula		18	4	1	...	23	...	9	3	...	...	12	...
,, Tibia,	simple	5	...	...	...	5	...	6	...	...	...	6	...
,, ,,	compound	1	...	...	...	1	...	...	...	...	...	...	...
,, Tibia and Fibula,	simple	16	1	...	...	17	...	24	3	1	...	28	...
,, ,,	compound	3	...	...	2	5	40.	6	1	...	...	7	...
,, ,,	comminuted	...	...	...	...	...	...	1	...	...	...	1	...
,, ,,	compound, comminuted	1	1	...	1	3	33.3	2	2	...	...	4	...
,, Foot and Toes,	with laceration, &c.	5	2	1	...	8	...	2	4	...	...	6	...
,, Spine		1	...	...	1	2	50.	1	2	...	...	3	...
Total results		124	73	7	16	220		106	113	2	6	227	
General per centage		56.36	33.18	3.18	7.22			46.7	49.3	.8	2.6		

* One died of cancer of breast.

† Convalescent from injury.

K.—INJURIES OF BONES.

SUB-DIVISIONS.		1848.						1849.					
		Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Fractures of the Cranium,	simple	2	...	...	4	6	66.6	...	...	...	3	3	100.
,, ,,	compound	1	...	...	3	4	75.	...	1	...	...	1	...
,, Nose,	simple	3	2	...	...	5	...	...	1	...	...	1	...
,, ,,	compound	...	...	...	...	...	...	...	1	...	...	1	...
,, ,,	compound, comminuted	1	1	...	...	2	...	...	...	...	...	...	...
,, Jaws,	simple	1	2	...	...	3	...	...	10	...	...	10	...
,, ,,	compound	...	1	...	...	1	...	...	...	...	...	...	...
,, Ribs,	.....	16	14	...	...	30	...	11	17	...	...	28	...
,, Clavicle,	simple	8	8	1	...	17	...	4	10	...	...	14	...
,, ,,	comminuted	1	2	...	...	3	...	...	...	...	...	...	...
,, Scapula,	.....	1	2	...	...	3	...	...	...	...	...	...	...
,, Humerus,	simple	10	9	...	...	19	...	8	9	..	...	17	...
,, ,,	double and compound..	1	...	...	...	1	...	...	...	...	...	...	...
,, ,,	ununited	...	...	1	...	1	...	...	...	...	...	...	...
,, Radius,	.....	3	8	...	...	11	...	2	19	...	...	21	...
,, Ulna,	simple	2	1	...	...	3	...	1	7	...	...	8	...
,, ,,	double.....	...	...	...	...	...	...	...	1	...	...	1	...

I.—INJURIES AND DISEASES OF THE EYES, EARS, AND NAILS.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Diseases of the Conjunctiva	6	4	...	...	10	...	1	6	...	...	7	...
Iritis	3	1	...	...	4	...	...	3	3	...	6	...
Corneitis	...	...	...	...	...	...	...	...	1	...	1	...
Aquo-capsulitis	...	...	...	...	...	...	1	...	...	...	1	...
Amaurosis	...	...	2	...	2	...	...	...	...	...	...	...
Inflammation of the Lachrymal Canal	1	1	...	...	2	...	...	...	...	...	...	...
Wounds	2	7	1	...	10	...	...	3	...	...	3	...
Burns	4	3	...	...	7	...	2	...	...	...	2	...
Otitis and Deafness	1	...	...	...	1	...	1	...	...	...	1	...
Onychia	...	...	...	...	...	...	2	...	...	...	2	...
Total results	17	16	3	...	36		7	12	4	...	23	
Total per centage	47.22	44.45	8.33	...			30.4	52.2	17.4	...		

Patella,	dislocation	...	...	...	...	...	...	1	...	...	...	1	...
Knee,	sprain	4	1	...	...	5	..	1	9	...	...	10	...
	contusion	13	9	...	...	22	...	13	13	...	...	26	...
	wound into joint	3	...	...	.	3	.	1	1	...	...	2	...
	inflammation	22	12	5	1	40	2.5	10	15	3	...	28	...
	disease	6	9	2	2	19	10.5	1	4	8	...	13	...
	loose cartilage in joint	1	...	...	...	1	...	...	1	...	...	1	...
	weakness of ligaments	1	...	1	...	2	...	...	...	...	...	...	...
	contractions of tendons	...	...	1	...	1	...	...	...	...	...	...	...
	inflamed bursæ	17	3	1	...	21	...	15	3	1	...	19	...
Ankle,	sprain	13	9	...	...	22	...	31	17	...	...	48	...
	contusion	2	2	...	...	4	...	9	4	...	...	13	...
	inflammation	7	1	...	...	8	...	4	...	..	...	4	..
	disease	2	2	6	1	11	9.09	...	2	1	...	3	...
	weakness of ligaments	...	...	...	...	...	..	...	1	2	...	3	...
	dislocation, compound	...	...	...	...	...	...	...	...	...	1	1	100.
Toe,	disease	...	...	1	. .	1	...	...	...	...	...	...	...
	supernumerary	...	...	...	...	...	...	1	...	...	...	1	...
Club Feet	.....	2	6	1	...	9	...	3	3	1	...	7	...
Muscles,	rupture	1	...	...	...	1	...	2	...	...	...	2	...
	contraction	...	...	...	...	...	...	1	...	...	...	1	...
Tendo Achillis,	rupture of	...	...	...	...	...	...	1	..	...	...	1	...
	Total results	116	81	25	4	226		117	114	28	3	262	
	General per centage	51.33	35.84	11.06	1.77			44.6	43.5	10.7	1.2		

H.—INJURIES AND DISEASES OF JOINTS, BURSÆ, LIGAMENTS, MUSCLES, &c.

SUB-DIVISIONS.		1848.						1849.					
		Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Clavicle,	dislocation	2	...	...	...	2	...	1	...	...	1	2	50.
Shoulder,	contusion	1	2	...	...	3	...	1	2	...	...	3	...
	disease	...	...	...	...	...	...	...	...	1	...	1	...
	dislocation	2	1	...	...	3	...	2	5	...	...	7	...
Elbow,	contusion	...	3	...	...	3	...	2	2	...	...	4	...
	wound into the joint	1	...	...	...	1	...	...	1	...	...	1	...
	inflammation	1	3	...	...	4	...	...	2	...	...	2	...
	disease	...	...	2	...	2	...	1	4	2	...	7	...
	dislocation	2	2	...	...	4	...	4	3	1	...	8	...
Wrist,	sprain	1	1	...	...	2	...	1	1	...	...	2	...
	disease	...	1	1	...	2	...	...	1	...	...	1	...
	dislocation	...	1	...	...	1	...	...	1	...	...	1	...
Hand,	thecal abscesses	...	...	...	...	...	...	1	8	3	...	12	...
Fingers,	disease	...	...	...	...	...	...	...	1	...	...	1	...
	dislocation	...	...	...	...	...	...	...	2	1	...	3	...
Back,	sprain	2	3	...	...	5	...	2	1	...	...	3	...
Hip,	contusion	3	1	...	...	4	...	4	4	...	...	8	...
	inflammation	7	4	...	...	11	...	2	1	...	...	3	...
	disease	...	5	4	...	9	...	1	2	4	1	8	12.5
	dislocation	...	...	...	...	...	...	1	...	...	...	1	...

G.—INJURIES AND DISEASES OF THE GENITO-URINARY SYSTEM.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Bladder—Calculus	3	...	...	...	3	...	1	...	...	...	1	...
,, Cystisis	1	1	1	...	3	...	...	3	...	...	3	...
,, Foreign body in	...	...	...	...	...	...	...	...	...	1	1	100.
,, Prolapsus	...	...	...	...	...	...	...	...	1	...	1	...
Urethra—Stricture	4	5	3	...	12	...	1	9	1	...	11	...
,, Retention of Urine	2	4	...	...	6	...	3	4	1	...	8	...
,, Extravasation of Urine	1	1	...	...	2	...	1	...	...	1	2	50.
,, Rupture	1	1	...	...	2	...	...	...	...	...	...	...
,, Hæmorrhage from	...	...	...	...	...	...	1	...	...	...	1	...
,, Fistula	...	2	...	...	2	...	...	...	...	...	...	...
,, Tumour from	1	...	...	...	1	...	...	...	...	...	...	...
Testicle—Orchitis	5	3	1	...	9	...	2	6	2	...	10	...
,, Contused	...	...	...	...	...	...	1	2	...	...	3	...
,, Scrofulous disease	...	2	...	...	2	...	...	1	...	...	1	...
,, Malignant disease	1	...	1	...	2	...	...	...	...	...	...	...
,, Hydrocele	4	1	...	...	5	...	...	2	1	...	3	...
,, Varicocele	1	...	1	...	2	...	...	...	...	...	...	...
Scrotum—Ulceration of	1	1	...	...	2	...	...	...	...	...	...	...
,, Laceration	...	...	...	...	...	...	1	...	...	...	1	...
Venereal disease	2	2	1	...	5	...	2	4	1	...	7	...
Contusions, inflammation, suppuration, &c., in Penis	2	2	...	...	4	...	3	4	...	...	7	...
,, ,, ,, in Vagina	13	1	1	...	15	...	8	5	5	...	18	...
Total results	42	26	9	...	77		24	40	12	2	78	
General per centage ...	54.55	33.76	11.69	...			30.8	51.3	15.4	2.5		

F.—DISEASES OF THE LYMPHATIC AND GLANDULAR SYSTEMS.

SUB-DIVISIONS.	1848.						1849					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Inflammation of the Lymphatics of the upper extremities	4	1	...	...	5	...	2	3	...	...	5	...
,, Lymphatics of the lower extremities	3	...	...	2	5	40.	6	1	...	...	7	...
,, Glands of the Neck	...	6	2	...	8	...	1	5	2	...	8	...
,, Groin	6	7	...	...	13	...	5	3	...	...	8	...
,, Axilla	1	...	1	...	2	...	4	1	...	...	5	...
,, Mammæ.....	1	4	...	...	5	...	1	3	...	...	4	...
Total results	15	18	3	2	38		19	16	2	...	37	
General per centage.....	39.47	47.37	7.89	5.27			51.3	43.2	5.4	...		

E.—INJURIES AND DISEASES OF THE INTEGUMENTS, &c.

SUB-DIVISIONS.	1848. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	1849. Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Contusions of the Head and Face	13	8	...	...	21	...	9	4	1	...	14	...
,, Chest, Back, and Bowels	17	5	...	...	22	...	30	16	2	...	48	...
,, Upper Extremities	2	9	1	...	12	...	3	5	...	...	8	...
,, Lower Extremities	27	18	1	...	46	...	19	10	3	1	33	3.3
,, General	7	6	...	...	13	...	5	5	...	...	10	...
Wounds of the Head and Face	22	52	3	...	77	...	20	31	5	...	56	...
,, Chest and Back	...	...	...	...	...	...	1	...	...	1	2	50.
,, Upper Extremities	2	8	...	...	10	...	5	5	...	...	10	...
,, Lower Extremities	20	9	...	...	29	...	22	16	...	1	39	2.3
,, Gun-shot	1	5	...	1	7	14.3	...	3	1	...	4	...
,, Bites by Dogs, &c.	...	1	...	...	1	...	4	3	...	...	7	...
Inflamn. & suppuration in the Chest, Back, & Bowels	3	2	...	...	5	...	2	1	...	1	4	25.
,, ,, Upper Extremities	3	7	...	...	10	...	3	3	...	...	6	...
,, ,, Lower Extremities	33	9	...	1	43	2.3	17	8	1	1	27	3.7
Ulcerations of the *Face and Neck	...	...	...	...	...	...	...	...	...	1	1	100.
,, Upper Extremities	...	1	...	...	1	...	...	1	1	...	2	...
,, Lower Extremities	33	26	6	...	65	...	22	42	6	...	70	...
Cancer of the Face	...	...	...	...	...	...	...	...	1	...	1	...
Eruptions	7	1	1	1	10	10.	...	...	...	...	...	...
Burns	12	5	2	14	33	42.4	10	13	5	15	43	34.8
Scalds	17	5	...	3	25	12.	20	9	1	...	30	...
Contractions	...	2	4	...	6	...	...	2	...	...	2	...
Total results	219	179	18	20	436		192	177	27	21	417	
General per centage	50.23	41.05	4.13	4.59			46.04	40.04	6.5	5.04		

* Death caused by erysipelas.

L.—DISEASES OF BONES.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
*Of the Cranium	...	...	...	...	...	...	2	...	...	1	3	33.3
,, Nose	...	1	...	...	1	...	...	1	...	...	1	...
,, Jaw	...	1	...	...	1	...	...	1	...	...	1	...
,, Ribs and Sternum	...	1	...	1	2	50.	...	2	...	...	2	...
,, Spine	...	4	4	...	8	...	...	1	2	1	4	25.
,, Spine, Curvature	...	1	6	...	7	...	1	4	9	...	14	...
,, Pelvis	...	...	...	...	...	...	...	...	1	...	1	...
,, Superior Extremities	2	6	2	...	10	...	1	5	...	...	6	...
,, Inferior Extremities	2	10	9	...	21	...	...	10	3	1	14	7.1
,, †Periostitis	3	9	...	1	13	7.6	7	6	...	...	13	...
Total results	7	33	21	2	63		11	32	15	3	59	
General per centage ...	11.11	52.38	33.34	3.16			15.2	54.19	25.4	5.		

* Death caused by erysipelas. † Death caused by apoplexy.

M.—TUMOURS.

SUB-DIVISIONS.	1848.						1849.					
	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.	Cured.	Made Out-patients.	Relieved, Incurable, &c.	Died.	Total.	Per centage of Deaths.
Malignant	1	3	1	1	6	...	2	4	...	1	7	14.3
Fibro-cellular	4	3	...	...	7	...	1	...	...	...	1	...
Fatty	1	4	1	...	6	...	1	1	1	...	3	...
Encysted	1	3	...	...	4	...	1	2	...	...	3	...
Vascular	...	1	...	...	1	...	...	...	...	...	...	...
Total results	7	14	2	1	24		5	7	1	1	14	
General per centage	29.17	58.33	8.33	4.17			35.7	50.	7.2	7.2		

SUB-DIVISIONS.	1848.				1849.			
	Cured.	Died.	Total,	Per centage of Deaths.	Cured.	Died.	Total.	Per centage of Deaths.
Amputations	10	2	12	16.6	14	...	14	...
Hernia	4	3	7	42.8	5	2	7	28.6
Lithotomy	3	...	3	...	1	...	1	...
Ligature of Femoral Artery	...	...	...	...	1	...	1	...
Trephining	...	1	1	100.	...	...	...	...
Tracheotomy	...	...	...	...	1	2	3	66.6
Transfusion	...	...	...	...	...	1	1	100.
Reduction of old dislocations	1	...	1	...	1	...	1	...
Tumours	9	...	9	...	8	...	8	...
Castration	2	...	2	...	...	...	...	...
Miscellaneous	46	...	46	...	38	...	38	...
Total results	75	6	81		69	5	74	
General per centage	92.59	7.48			93.2	6.8		

EXPLANATION.

In referring to the headings "Cured" and "Made Out-patients," it will be seen that the numbers are very nearly equal. In explanation of this it is necessary to observe, that all patients, whether convalescent or otherwise, who were continued under treatment after their discharge from the wards, were classified as "Out-patients." It was not until after the report had been completed that it was deemed advisable to add an additional column for convalescent patients, and time would not then admit of the alteration.

ON THE CAUSES

WHICH

EXCITE AND INFLUENCE RESPIRATION

IN

HEALTH AND DISEASE.

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It is not my object in the following Address to investigate either the essential nature of respiration, which consists in the changes which it effects on the organism,—or the channels by which air enters the system, whether through the lungs, the gills, or the skin, with or without the aid of a circulation,—or the mechanism by which respiration is effected. I propose to myself to investigate the various causes which excite and influence the respiratory movements.

But though the essential nature and mechanism of respiration form, as such, no part of the present inquiry, yet it is necessary that the successive stages of the respiratory act should be clearly stated before considering the first stage of that great act, namely, the causes which excite respiration. I shall therefore attempt to sketch the essential nature and the mechanism of respiration, before I proceed to the investigation of the causes by which it is excited.

THE CHANGES EFFECTED BY RESPIRATION ON THE ORGANISM.

Respiration, an essential function of life, lies at the root of physiology. Every living animal must part with the old materials of its fabric whilst it takes up fresh materials. The vegetable assimilates inorganic matter and renders it organic. The animal

assimilates the matter rendered organic by the vegetable, and then renders it again inorganic. As the sum of inorganic matter contains more oxygen than that of organic, the surplus oxygen must be parted with when the former is converted into the latter. Consequently the vegetable, in rendering matter organic, must part with the surplus oxygen, while the animal, in restoring the inorganic material, must receive sufficient oxygen to replace that which was lost.

Respiration is the converse to assimilation, the former act abstracting what the latter had deposited; they are both essential to life, but while assimilation may be suspended in all classes of animals, respiration must, in the higher classes, be continuous. Respiration is the combustion of what has been assimilated. It consists more particularly, but not exclusively, in the combustion of the hydro-carbonaceous materials, and their conversion into water and carbonic acid by the oxygen of the respired air, and in the removal from the system of the carbonic acid when formed.

The vigour of life is in direct proportion to the activity with which the organic materials are rendered inorganic. If an animal hybernate, life being latent, the organic materials are almost or quite unchanged; little or no air is supplied; respiration is scarcely performed; the animal functions are almost suspended. If, on the other hand, an animal attack its prey, life is roused to the utmost; the organic materials of the body are rapidly changed; air is supplied plentifully; respiration is vigorous; the animal functions are performed with the utmost power.

Between the two extremes of latent hybernating life coupled with suspended respiration, and energetic life coupled with vigorous respiration, there is every variety and shade of the exercise of life and respiration; and in every instance the amount of respiration and of the combustion of organic matter exactly corresponds with the degree of vitality exercised.

At the same time that the functions of one organ are vigorous those of another may be suspended; the organic changes go on rapidly in the organ at work, but slowly, or not at all, in that which is inactive. The combustion of each organ varies as the exercise of its functions varies.

During the successive stages of life, the exercise of respiration and of the animal functions are exactly proportioned to each other,

and to the wants of the particular stage. The restlessness of the child and the activity of the boy correspond to their excited respiration, and the quick repair and waste of their frame. The calmness and power of the man are combined with a usually tranquil respiration, capable of being increased to the utmost as the occasion calls for the higher energies of life. In the old man, deliberate in his movements, respiration is limited and usually slow, being proportioned to the slow change of his organic structures.

The same law that rules the corresponding vitality and respiration of an individual animal during the varied functions of its life also regulates the whole scale of animal life. In the carnivorous mammal, life is energetic, respiration vigorous, and the organic change rapid. In the reptile, life is torpid, respiration feeble, and the organic change slow. The vital energies, the respiration, and the organic change of each animal are in exact proportion to each other, and to the purpose in life for which the animal is fitted.

In the higher grades of animal life respiration must be constantly kept up when the vitality and functions are active; but it may be suspended when they are dormant, as in syncope and hybernation. In the lower grades respiration can be suspended for a time without injury to life; the period of possible suspension being longer or shorter, in proportion as the organic functions are lower or higher.

In all animals, whether they have or have not a circulation,—whether they respire through lungs, gills, the skin, air tubes, or air sacs,—whether they have or have not a special respiratory apparatus—the essential part of respiration is performed throughout the whole organism.

In those beings destitute of a circulation, the air must be diffused by endosmosis through the whole frame-work. In those animals which possess a circulation the air enters the blood through a special apparatus, or through the skin, and is transmitted by the circulation to the various structures. In these the essential function of respiration is performed around and within the systemic capillaries.

The essential function of respiration consists in the oxygenation of every part of the organism. Respiration is allied to combustion. If we light a candle, the combustion consists neither in the supply of oxygen nor the removal of carbonic acid, but in the chemical

union of oxygen and carbon. In like manner, if we breathe, respiration does not essentially consist either in the supply of oxygen or the removal of carbonic acid, but in the chemical union of the oxygen with the hydro-carbons and with the other organic materials. Again, if we light a candle, it is necessary to the continued combustion that the oxygen be supplied as rapidly as it is consumed, and the carbonic acid removed as rapidly as it is formed, else in either case the flame will be quenched. So again, if we breathe, it is necessary to the continued respiration that the oxygen be continuously supplied to the system, and that the carbonic acid, and the other noxious combinations formed, be continuously eliminated from the organism, else in either case those chemical changes in the organism, which constitute the essential function of respiration, will be no longer performed.

There is no difference in the mode of respiration, whether the oxygen enter the organism through the medium of lungs, gills, or any other special breathing apparatus, or through the medium of the skin. In those animals possessing pulmonary respiration, the essential part of respiration is not performed in the lungs. The oxygen is admitted inwards through the lungs to the circulating blood, and is transmitted over the whole organism by the circulation, and the carbonic acid formed throughout the organism is conveyed outwards by the circulation, is rendered free in the lungs, and is expelled thence during expiration. If respiration be cutaneous, oxygen is continuously admitted into the organism, and carbonic acid expelled from it, through the medium of the skin. The frog, which usually respires simultaneously both through the lungs and the skin, may respire through the medium of the lungs alone or of the skin alone. Dr. Edwards kept frogs immersed for months in aerated water, so that they could not breathe through the lungs. They lost their characteristic activity and became sluggish, but they lived for an indefinite period. Pulmonary and cutaneous respiration are essentially alike, but the oxygen is admitted over an infinitely more extensive surface through the lungs than through the skin. The lungs form the most perfect respiratory apparatus, simply because they admit the greatest quantity of oxygen into the system, and are consequently connected with the most rapid oxygenation of the whole organism and the most energetic performance of all the vital functions. The frog,

when it breathes through the skin alone, is far lower in vitality, and its organism is less rapidly oxygenated, than when it breathes both through the lungs and the skin.

The circulation in those animals endowed with a circulation, in addition to its proper functions, forms an integral part of the respiratory apparatus; by it the oxygen is diffused over, and the carbonic acid collected from, the whole organism. The circulation is indeed not only the great and diffused channel for the supply of fresh and the elimination of effete material, but it is also the great and diffused respiratory channel for the supply of oxygen and the removal of carbonic acid.

Besides being the great respiratory channel, the circulation is also a seat of the essential function of respiration, the blood being itself oxygenated by the oxygen diffused through it. Indeed, the essential function of respiration is only performed in the lungs, insomuch as the blood circulating through them is being oxygenated, and as the small portion of organic tissue forming the texture of the lung is like every other organic texture, subject to respiratory oxygenation.

The circulation, viewed as a portion of the respiratory apparatus, is inspiratory in those parts of the current which convey the oxygen from the lungs to the left cavities of the heart, and thence over the whole organism; and it is expiratory in those currents which convey the carbonic acid from the whole organism through the veins to the right cavities of the heart, and from those cavities to the lungs, where it is expelled. In the frog, when the respiration is pulmonary, the inspiratory portion of the circulation conveying the oxygenated blood from the lungs is poured into the left auricle; but when the respiration is altogether cutaneous, the inspiratory current is changed, and the oxygenated blood is poured into the right auricle.

When the blood is increasingly charged with carbonic acid, it produces increasing distention of the capillaries, and causes greater and greater impediment to the circulation, in the manner so well illustrated by Dr. Williams. When, on the other hand, the blood is charged with oxygen, it produces tonic contraction of the capillaries, and causes quickening of the circulation. The perpetually renewed supply of oxygen to the blood is therefore necessary, in order that the blood circulating in the capillaries,

charged with carbonic acid, may be forced onwards with greater ease by the action of the heart.

We perceive, then, that while respiration thus essentially consists in the combination of oxygen with the effete materials of the organism in order that they may be eliminated, we also see that the supply of oxygen, and the evolution of carbonic acid, are necessary to the continuance of respiration.

Animal heat is the great product of respiration. It is not, however, from the chemical action of respiration alone that animal heat is evolved,—it is, in fact, the common product of all the chemical and electrical, and of many of the mechanical processes, constantly going on throughout the organism. Heat is evolved by the chemistry of the assimilation and formation of the tissues, as well as by the chemistry of the decomposition and elimination of the tissues. The formation of carbonic acid is undoubtedly the chief source of animal heat. The production of animal heat is so much under the control of the nervous influence that I shall consider separately the remarkable effects of that influence.

Effect of the Nervous Influence on the Production of Animal Heat.

Sir Benjamin Brodie found that when he killed an animal, either by pithing or by means of the wourali poison, and kept up artificial respiration, the temperature of the body fell more quickly than it did when the body lay undisturbed, notwithstanding that the venous blood was converted into arterial, and that carbonic acid was evolved almost to the normal amount.

The effect of the nervous influence, and of natural and artificial respiration, on the evolution of animal heat, is well illustrated by the accompanying table, which presents at one view the various tables given by M. Chossat in his remarkable and important Memoir on the influence of the nervous system on the animal heat.

This table demonstrates that the withdrawal of the nervous influence lessens the production of animal heat, whether by removal of the brain, division of the spinal marrow, or the administration of opium, the respiration being in those instances automatic,—or by division of the medulla oblongata, respiration being artificial.

The nerves exercise a local influence on the evolution of animal heat. Elliott and Home observed, that after dividing the nerves

TABLE COMPRISING VARIOUS TABLES GIVEN BY M. CHOSSAT IN HIS MEMOIR ON THE INFLUENCE OF THE NERVOUS SYSTEM ON ANIMAL HEAT.

	Dog. Killed by dividing the spinal marrow in the neck. Body exposed, undisturbed.		Dog. Killed by a blow on the occiput. Circulation kept up by artificial respiration.		Dog. Brain removed above the pons varolii.				Dog. Section of spinal marrow below occiput. Slow artificial respiration. Temperature before operation 103°.8.		Dog. section of spinal marrow below seventh cervical vertebra. Temperature before opcration, 105°.8.				Dog. Section of spinal marrow below third dorsal vertebra.				Dog. Section of spinal marrow below seventh dorsal vertebra.				Dog. Injection of solution of opium into the veins.				Dog. Division of the pneumogastric nerves: a tube was inserted into the trachea.				
	Rate of cooling.		*Rate of cooling.*				*Rate of cooling.*		*Rate of cooling.*				*Rate of cooling.*				*Rate of cooling.*						*Rate of cooling.*						*Rate of cooling.*	
	Actual temperature.	Loss of heat.	Actual temperature.	Loss of temperature	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperatute.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of tempetature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.		Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.
At the time of death or operation ...	104°.9	...	103°.46	...	...	...	104°.	...	99°.86	...	...	...	104°.9	...	...	...	104°.9	...	...	...	105°.44	...	102	8	103°.64	...	Before operation	85	10	102°.	...
End of the 1st hour	101°.66	3°.24	99°.86	3°.6	52	11	99°.5	4°.5	96°.08	3°.78	130	20	98°.96	5°.94	100	32	101°.66	3°.34	128	21	101°.66	3°.78	173	20	97°.88	5°.76	Time of operation ...	180	4½	97°.	5°.
,, 2nd ,,	96°.98	7°.92	95°.54	7°.92	131	74	94°.64	9°.36	91°.4	8°.46	106	19	94°.1	10.°88	153	27	98°.06	6°.84	145	18	100°.94	4°.50	157	15	93°.74	9°.90	Average 1st 12 hours	215	6	99°.2	2°.8
,, 3rd ,,	93°.02	11°.88	91°.76	11°.7	153	101	89°.06	14°.94	87°.26	12°.62	88	22	89°.14	14°.76	155	15	94°.82	10°.08	140	19	101°.88	3°.56	139	11	90°.68	13°.	,, 2nd 12 hours	190	5	99°.1	2°.9
,, 4th ,,	89°.06	15°.84	88°.34	15°.12	125	91	86°.9	17°.1	Cessation of artificial respiration.		78	16	86°.	18°.9	...	...	...	...	151	22	102°.74	2°.70	114	9	88°.14	15°.5	,, 3rd 12 hours	183	6	98°.6	3°.4
,, 5th ,,	85°.46	19°.44	85°.1	18°.36	103	76	85°.46	18°.54	...	...	...	17	83°.3	21°.6	...	...	...	...	117	22	103°.46	1°.98	93	7	85°.64	18°.	,, 4th 12 hours	106	4	85°.1	16°.9
,, 6th ,,	82°.94	21°.96	82°.4	21°.06	79	40	84°.2	19°.8	...	...	...	16	80°.78	24°.12	...	...	...	...	140	24	104°.9	°.54	74	6½	83°.48	20°.16	During 5th period of 12 hours. 3rd hour	58	5	78°.1	23°.9
,, 7th ,,	81.°32	23°.58	80°.6	22°.86	51	11	81°.86	22°.14	...	...	...	...	79°.34	25°.56	68	6	82°.4	22°.5	150	27	105°.08	°.32	56	6	81°.5	22.°14	6th hour	39	4	72°.86	29°.14
,, 8th ,,	...	...	78°.62	24°.84	41	13	80°.6	23°.4	...	...	...	...	...	...	44	7	80°.78	24°.12	...	...	...	...	45	5	80°.24	23°.4	9th hour	24	5	70°.5	31°.5
,, 9th ,,	78°.26	26°.64	76°.82	26°.64	41	14	79°.34	24°.66	...	...	26	11	75°.2	29°.7	35	7	79°.52	25°.38	176	31	103°.1	2°.34	...	...	...	...	12th hour.....	23	3	69°.26	32°.74
,, 10th ,,	...	...	74°.3	29°.16	28	14	77°.72	26°.28	...	...	Death.				31	7	78°.44	26°.46	...	...	...	...	39	5	79°.16	24°.48	Death.				
,, 11th ,,	75°.02	29°.88	72°.14	31°.32	30	13	76°.46	27°.54	...	...	...	...	...	...	28	7	77°.36	27°.54	...	...	101°.66	3°.70	...	...	...	...					
,, 12th ,,	...	...	Death, *i.e.*, cessation of circulation.		29	13	75°.2	28°.8	...	...	...	...	...	...	24	8	76°.1	28°.8	160	25	101°.3	4°.14	38	5	79°.7	24°.					
					Death.				...	...	...	...	...	...	...	...	...	...	Died after thirty hours.				Before death, 22nd hour,								
															17th hour died		71°.6	33°.3					13	...	73°.	30°.6					

of a limb, its temperature falls. Mr. Earle noticed that the temperature of the hand of a paralysed limb was 70,° while that of the sound hand was 92.° When the paralysed limb was electrified its temperature rose to 77°.

Throughout the scale of animal life, the lower the nervous energy the lower is the animal heat, and the higher the nervous energy the higher is the animal heat. The sluggish mollusca possess a temperature either the same with, or only a very little higher than, the surrounding medium. Insects, in their perfect state, possess the power of evolving much heat, the larva generates less heat than the perfect insect, while the pupa evolves less heat than the larva. When the bee is excited it has a much higher temperature than when quiescent. Mr. Newport disturbed a hive of bees in winter, when the external temperature was 34½°; the temperature of the disturbed hive rose to 102°, while that of an adjoining hive was only 48½°. Among fishes, the eel is scarcely warmer than the surrounding medium, while the bonito, whose gills are amply supplied with nerves, has, according to Dr. Davy, a temperature 18½° above that of the sea. For numerous interesting illustrations of the dependence of the power of generating heat, on the possession of nervous energy, I refer to Dr. Carpenter's Work on comparative physiology.

We find on all sides evidence that the evolution of animal heat is dependent on the exercise of the nervous influence. It is the possession, not of a larger or smaller nervous system, but of a higher or lower nervous energy, which regulates the production of animal heat.

On the combined Action of Respiration and the Nervous Influence on the Evolution of Animal Heat.

The experiments of Sir Benjamin Brodie, while they prove that the nervous system controls the evolution of animal heat, seem at first to show that animal heat is not evolved by the chemical action of respiration; since a decapitated animal subjected to artificial respiration, although it produced almost the normal amount of carbonic acid, cooled more quickly than a recently killed animal, left undisturbed. These experiments, which form an era in the knowledge of the development of animal heat, and the functions of the nervous system, stimulated physiologists to further inquiry.

M. Legallois divided the spinal marrow and kept up artificial respiration in a rabbit, and he found that less oxygen was consumed and less carbonic acid evolved than had been consumed and evolved by the same rabbit when breathing naturally. He also found that the rabbit in which artificial respiration was performed cooled less quickly than a rabbit whose body was left undisturbed after being recently killed.

M. Chossat, in the experiments given in the table at page 186, found that the dog on which artificial respiration was performed after its brain was crushed, cooled less quickly during the first seven hours, and more quickly during the last four hours of its sustained existence, than the dog whose body was left undisturbed after the division of the spinal marrow between the second and third cervical vertebræ.

In Sir Benjamin Brodie's experiments, the artificial respirations were performed at the rate of from 30 to 35 in a minute.

Sir Charles Hastings found that when the lungs were inflated fifteen times in a minute in a rabbit just killed, the rate of cooling was diminished. In one of his experiments, the rabbit on which artificial respiration was performed, cooled only 4°, while that which was left undisturbed cooled 7.5°. Dr. Wilson Philip killed two rabbits, one he left undisturbed, and on the other he performed artificial respiration thirty times in a minute; in half-an-hour the latter had lost 4°, the former only 3°.7. He now inflated the lungs only twelve times in a minute, and in another half-hour the rabbit had only lost 2°.5 in addition, while the undisturbed rabbit had lost in the same time 3.5°. This experiment at once confirms and explains the previous experiments of Sir Benjamin Brodie.

These experiments prove that animal heat is evolved during artificial respiration; that the evolution of animal heat is proportioned to the amount of carbonic acid generated; that respiration in its chemical actions is a warming process; and that respiration in its physical action is a cooling process.

Respiration is a warming process throughout the whole organism by means of the formation of carbonic acid and by other chemical changes. It is also probably a warming process in the lungs, inasmuch as it causes the conversion of oxygen from the gaseous to the liquid form when it is taken by endosmosis into the blood. During this process the latent heat must become sensible, and

cause an elevation in temperature of the blood in the pulmonary veins. Dr. Davy found the blood in the right cavities 1° warmer than that in the left; and he also found that the temperature of venous blood, when exposed to the air, rose from 1° to 2° under the influence of the absorption of oxygen.

Respiration is a cooling process, inasmuch as it causes the conversion into vapour of much of the watery part of the blood, which vapour escapes from the lungs during expiration, at a temperature of 98°, while the air which enters is cooler in proportion to the external temperature. This is the merely physical part of respiration, and is the same in effect with cutaneous perspiration; the same in effect also with ordinary evaporation. If any one enter a stove heated above 100°, the evaporation from the lungs and surface keeps down the temperature of the body. Delaroche and Berger placed a porous vessel containing two moistened sponges at a temperature of 100° to 106°, and a frog at 75°, in a stove at 126° to 142°. In a quarter of an hour the jar, the sponges, and the frog were all about blood-heat (98° to 100°), and in two hours they still retained that temperature. Here the physical effect of evaporation caused these bodies to retain a temperature from 28° to 42° below that of the surrounding medium.

Respiration, as a chemical or warming process, raises the temperature of the body throughout, but respiration, as a physical or cooling process, tends to lower the temperature. If the temperature of the surrounding medium be below the standard of animal heat, the chemical or warming processes of respiration overbalance the physical or cooling process, and the body is warmer than the atmosphere. If the temperature of the air be the same with that of the standard of animal heat, then the warming and cooling processes counterbalance each other, and the atmosphere and the body are alike in temperature. But if the external temperature be above the standard of animal heat, then the warming is over-balanced by the cooling process, and the body retains a temperature below that of the surrounding medium.

In Sir Benjamin Brodie's experiment, the cooling over-balanced the warming process, inasmuch as the cool air with which the lungs were inflated was warmed in the lungs at the expense of the heat of the body; and the warm blood in the course of its circulation was conveyed in continued currents from the centre to the

surface, where it was cooled rapidly by cutaneous evaporation. Notwithstanding the rapidity of the artificial respiration, the undisturbed body cooled almost as quickly as the other. It is clear that some animal heat must have been generated, to compensate for the greatly augmented rate of cooling called into play by the currents of circulation and of artificial respiration.

The experiments of Legallois show that the chemical or warming processes of respiration are not performed so efficiently during artificial as during natural respiration; and those of Dr. Wilson Philip and Sir Charles Hastings show that when the physical or cooling process of respiration is not performed with undue vigour, the cooling of the body is delayed, instead of being hastened, by artificial respiration, and that consequently a considerable amount of animal heat must be evolved under the influence of that process.

The proofs that the evolution of animal heat is dependent on respiration in co-operation with the nervous influence are not confined to the experiments with artificial respiration detailed above; they are derived also from careful and accurate observations made on animals when in a state of hybernation and of sleep.

On the 21st of Jan., 1806, the temperature being 29°.3, M. Saissy irritated a hedgehog, a dormouse, and a bat, when in a state of profound hybernation; the temperature of the two former was 37°.4, of the bat 39°.2. The dormouse awoke in three-quarters of an hour; in an hour its temperature was 77°, and in two hours 95°.8. The bat awoke at the end of an hour, when its temperature was 69°; and in two hours it was 80°.6. The hedgehog did not awake for two hours, when its temperature was 54°.5; in three hours it was 86°, and in four hours 89°.6. If the rise in temperature had been solely due to the awakened nervous energy, the increase in temperature would not have been so slow and progressive. That it was really due to the combined influence of the respiration and the aroused nervous energy, is proved by M. Saissy's experiments, detailed in the accompanying table, from which it will be observed that as the warmth of the animals declined under the influence of the declining external temperature, the number of respirations and the amount of oxygen diminished *pari passu*.

TABLE showing the number of cubic inches of oxygen consumed in an hour by the respective hybernating animals, in Summer and Winter, under increasing degrees of cold and insensibility; and the temperature of the animals in the armpit, made from various details in M. Saissy's Researches on Hybernating Animals.

CUBIC INCHES OF OXYGEN CONSUMED PER HOUR, BY	Hedgehog.		Dormouse.		Bat.	
	Temperature of Animal.	*Oxygen consumed.*	*Temperature of Animal.*	*Oxygen consumed.*	*Temperature of Animal.*	*Oxygen consumed.*
12th of August, 1806. Temp. 64°.4; animals lively	...	80.8	...	34.6	...	17.88
6th of August. Temperature of animals	95°	...	97°.5	...	86°	...
8th of November. Temperature of air 44°.6, animals still conscious	38°.5	26.59	69°.8	20.53	53°.6	3.84
1st of February. Temperature of air 29°.3, animals hybernating but breathing; the temperature rose during the observation	38°.5 rising to 44°	2.03	38°.5 rising to 44°.6	1.15	...	...
2nd of February. Temperature of air 32°, animals hybernating profoundly, not breathing	38°.5	...	38°.5	...	37°.4	...
NUMBER OF RESPIRATIONS PER MINUTE:—						
8th of August. Temperature 68°	16		45		70	
10th of November. Temperature 44°.6; animals conscious	10		30		8	
When hybernation was commencing	4 to 5		9 to 10		5 to 6	
Profound hybernation	...		...		...	
CIRCULATION. NUMBER OF PULSATIONS:—						
9th of August, 66°.2	75		105		30	
11th of November, 44°.6	25		60		30	
Beginning to hybernate	...		20 to 25		...	
Profound hybernation	9 to 10		9 to 10		9 to 10	

Thus, on the 8th of Nov., when the animals were still conscious, the amount of oxygen consumed by the bat was about $\frac{1}{5}$th of the normal proportion, and its temperature was reduced to 53°.6: the consumption of oxygen by the hedgehog was reduced to $\frac{1}{3}$rd, and its temperature had fallen to 56°.5: the dormouse, however, still consumed as much as $\frac{2}{3}$rds of the normal proportion of oxygen, and its temperature had only fallen to 69°.8. When those animals were in a profound state of hybernation they consumed no oxygen, and their temperature was as low as 38°.5, but when, owing to slight disturbance, the hedgehog consumed $\frac{1}{40}$th and the dormouse $\frac{1}{30}$th, of the normal amount of oxygen, the temperature of those animals rose during eight hours, the hedgehog from 38°.5 to 44°, and the dormouse from 38°.5 to 44°.6.

The experiments of Dr. Marshall Hall afford additional proof of the dependence of animal heat on the combined influence of the nervous energy and respiration. He found that a bat in a perfect state of hybernation did not absorb any oxygen for the space of ten hours. After the lapse of that period, it was gently roused from time to time, and in two hours and ten minutes it had absorbed one cubic inch of oxygen. It was then much roused; it moved about incessantly, and in one hour it had absorbed five cubic inches of oxygen. From another observation, he found that an animal in a perfect state of hybernation absorbed 3.4 cubic inches of oxygen during sixty hours. Dr. Marshall Hall roused a bat in a state of hybernation by inserting a thermometer into the stomach, when the temperature was 39° ; an hour afterwards the animal was lively and respiring quickly, and the temperature of its stomach was 95°.

The whole subject is illustrated in a very interesting manner, and the dependence of animal heat on the combined influence of the nervous energy and of respiration is proved by the observations of Mr. Newport, on the Temperature and Respiration of Insects, in the *Philosophical Transactions* for 1835 and 1837.

Mr. Newport found that the temperature of the full-grown larva of the sphinx, when inactive, was .3° above that of the atmosphere; but when, owing to its being excited it became active, it rose to 1.3° above the surrounding medium. The number of respirations and the amount of carbonic acid evolved were much greater when the larva was active than when it was inactive.

The temperature of the undisturbed pupa is not pereeptibly higher than that of the atmosphere; when disturbed, it may rise from 1° to 2°. The larva of the sphinx at a temperature of 70° produced .086 cubie ineh of carbonie acid gas in an hour, while the pupa only produeed .0012 eubic ineh in the same period when exposed to a temperature of 46°. The produetion of earbonie acid by the pupa was inereased to .0022 cubie inehes in an hour when it was exposed to the higher temperature of 58°.

When the inseet is in its perfeet state, its temperature is higher while its respirations are more rapid and its produetion of earbonie aeid is greater than in either the larva or pupa state. The temperature and respiration of the perfeet inseet vary mueh, aeeordingly as it is in a state of aetivity or repose. The Sphinx Ligustri, shortly after it had ehanged from the pupa to the perfect state, had a temperature of only 4° above the atmosphere; in two hours and a quarter it had risen to 5°.2. Another speeimen, which had been exerting itself for a longer period, had a temperature of 9° above the surrounding medium.

The Bombus Terrestris, when first eaught, being then in a state of excitement, respired 120 times in a minute; in half-an-hour, the inseet being at rest, the respirations were only 58; in 140 minutes they had sunk to 46; and in 180 minutes they were no longer pereeptible. The Bombus Terrestris, when first captured, evolved .345 eubie ineh of earbonie aeid in the hour, but when at rest during twenty hours, the quantity evolved in the hour was redueed to .015, or less than the twentieth part. On placing these inseets in a box, it was found that when they were quieseent their temperature was 4° above the surrounding medium, but that, when they were exeited, it rose to 11° above the atmosphere. There are eertain individuals among these bees, named nurse bees, whieh have the remarkable power of raising their temperature at will, in order to impart warmth to the young bees in the cells by brooding over them. To do this, the bee fixes itself on the oceupied cell, respiring at first very gradually; it quickens its respirations to 120 or 130 in the minute, and exeites in the eomb a temperature 22° above the atmosphere. On one oeeasion, the temperature of the hive was 40° above that of the surrounding medium. In winter, when the bees were quiet, the temperature of the hives was sometimes the same with that of the atmosphere.

On tapping the hive, the bees were excited, respired quickly, and generated a great amount of heat. Once, on tapping a hive, its temperature rose to 102°, 67°.5 above the atmosphere! At the same time the temperature of a neighbouring hive was only 14° above the surrounding medium.

The various kinds of insects differ remarkably in the power of generating heat. This power is higher in volant than in creeping insects, in diurnal than in crepuscular insects. In all the various species, the individual temperature corresponds with the respiratory power,—the respiratory power with the habits of the insect. The degree of the respiratory power does not depend on the possession of a larger or a smaller nervous system, but on the possession of a higher or lower nervous energy. The higher the nervous energy the higher is the temperature and the greater the exercise of respiration.

The experiments in which artificial respiration was performed after the division of the nervous centres, the observations made on mammalia in a state of hybernation, and those on insects in their larva, pupa, and perfect state, in their torpid and active condition, prove that the evolution of animal heat is controlled by the nervous influence, and generated by respiration. The nervous influence and respiration co-operate *pari passu* in its production; respiration, the chemical agent, being regulated by the nervous influence, and excited in exact proportion to the nervous energy.

The co-operation of the Nervous Energy, Respiration, and Circulation in the Evolution of Animal Heat.

The circulation being an integral part of the apparatus of respiration, the energy of the circulation is of necessity increased when the action of respiration is augmented. Indeed if, from any cause, circulation be increased, respiration must be increased also. These positions are amply proved by observation and experiment.

In ordinary death, respiration ceases before circulation. If the animal be pithed, or destroyed by the wourali poison, the movements of respiration cease, but the circulation of the blood continues. The action of the heart, and finally the circulation in the capillaries also cease, unless respiration be maintained artificially. Circulation, then, outlives for a time pulmonary respiration; in the

frog, indeed, circulation can be carried on independently of pulmonary and in virtue of cutaneous respiration; the circulation, in fact, lasts for a considerable period after the cessation even of cutaneous respiration.

In the hybernating animal, the circulation maintains a condition almost parallel with the respiration, but the circulation continues during profound hybernation, when the respiration seems to be entirely suspended. M. Saissy observed, on the 9th of August, 1806, the temperature being 66°.2, that the heart of a dormouse pulsated 105 times in a minute; on the 15th of November, temperature 44°.6, the animal being still conscious, the heart beat 60 times. When the animals began to hybernate, the pulsations were reduced from 20 to 25, and when it was in a state of profound hybernation, the circulation in the arteries was not perceptible, the veins of the abdomen were congested, and the heart pulsated feebly only from 9 to 10 times in the minute. The parallel conditions of the respiration and temperature may be seen in the table given at page 191, from which it will be observed that as the external temperature fell, the animal heat, the respiration, and the circulation fell at equal rates, until the external temperature had been lowered to a certain extent, at which period the animal heat had fallen to about 38°, respiration was almost or altogether at a stand-still, and the circulation, though very feeble, was still in motion.

Dr. Marshall Hall observed the circulation, under the microscope, in the small vessels of the wing of the bat when in the state of complete hybernation; and although the respiration was suspended, the blood circulated slowly in the minute vessels, the pulsations being 28 in the minute.

The increase of circulation with that of respiration, and the increase of respiration with that of circulation, may be observed daily in the various acts of life.

Mr. Newport noticed that the rate of the circulation in the insect corresponded with its respiration, temperature, and activity. When the Sphinx Ligustri was greatly excited, the pulsations of its dorsal vessel were 139, and its respirations 42 in the minute, and its temperature was 5°.5 above the atmosphere. When at rest, half-an-hour later, the pulsations were 49, the respirations 18, and the temperature 5°. After an additional rest of three-quarters of an hour, when the insect was perfectly quiet, the pulsations were

only 42, and the respirations 15 in the minute, while the temperature was nearly 2° above that of the atmosphere.

In the larva, and still more in the pupa state, the lower condition of the activity, temperature, and respiration of the creature is attended by a correspondingly lower condition of circulation. When the larva of the sphinx was asleep, its pulsations were about 30 in the minute, and its temperature varied from .0 to .5° above the atmosphere; when it was aroused and active, its pulsations were 36, and its temperature was .9° above the surrounding medium. When the larva of the sphinx changed to the pupa state, its pulsations were only 12 in the minute, while its temperature was .3° above the atmosphere; as the pupa became more quiescent, the pulsations were undoubtedly less perceptible. It appears that the pulsations are more rapid in the earlier than in the later stages of the larva condition: the larva of the sphinx having 108 pulsations in the minute when ten days old and asleep, while it had only 26 pulsations when thirty-three days old, just before it had entered the earth for changing; but the pulsations, though quicker, are feebler in the earlier stages than the later.

The pulsations are diminished when the insect is asleep, but are increased in force and frequency immediately the insect awakes.

It appears then that in the order of the phenomena, the increased nervous energy and increased activity of the animal precedes the increased rate of circulation, of respiration, and of temperature.

ON THE MECHANISM OF RESPIRATION.

The decomposition and removal of the effete materials of the organism, and the evolution and regulation of animal heat, constitute in all animals the great purposes of respiration. In every animal, respiration is in exact accordance with the vital energies; if the vital energies be suspended, respiration is suspended; if they be active, respiration is active. In every being, whether there be or be not a special respiratory apparatus, such is the adjustment of the mechanism of respiration that the function of respiration can be suspended, diminished, or increased, in exact adjustment and proportion to the suspension, diminution, or increase of the energies of life.

The great purposes, the essential nature of respiration being alike in all beings, however simple or complex they may be in

construction and function, the causes which excite respiration must be the same in principle in all classes of animals; and as I shall have to draw many of the illustrations and proofs of those causes from the various classes of animals, I shall briefly review the principal varieties in the mechanism of respiration with which the different orders of beings are endowed.

Respiration has not been closely observed in those beings which are not endowed with a circulation. In the classes destitute of circulation, respiration must be carried on by the absorption of air through the integument and the organism from without inwards. In many of them the organs of locomotion, the cilia, constitute also organs of respiration, by causing the repeated renewal of the water in contact with the surface. In others, as the acalephæ, respiration is carried on through the medium of numerous channels diffused throughout the organism.

In all those animals which possess a circulation, the circulation must be regarded as an essential and subservient part of the mechanism of respiration. The circulatory apparatus is in every instance adapted to the respiratory apparatus, and not the respiratory to the circulatory. It is the object of every respiratory apparatus to present a surface capable of absorbing the oxygen of the atmosphere, and of passing it inwards to the blood through the walls of the blood-vessels. The oxygen received into the blood is transmitted onwards by the circulation through the whole organism.

Some creatures, as certain snails, the leech, and the lowest forms of crustacea, have no special respiratory organ; and in these respiration is altogether cutaneous. The constant renewal of fresh aerated water, or of air to the surface, is, in these beings, kept up, in some, by the motion of cilia, in others, by the movements of the animal itself. The rapidity with which the air enters the organism, according to the varying wants of the individual, is regulated by the varying rapidity of the animal movements, and of the circulation of the blood. In those animals whose respiration is exclusively cutaneous, the greatest proportion of oxygen is contained in the blood circulating in the cutaneous capillaries, and in the vessels proceding from those capillaries. All those animals which are endowed with a special respiratory apparatus are also endowed with cutaneous respiration. If the act of the special respiratory apparatus be suspended, the respiration may in some animals be carried on

entirely through the medium of the skin. Thus a frog may sustain its life indefinitely by cutaneous respiration, the action of the lungs being suspended, provided the animal functions be not performed with vigour.

It may perhaps in one sense be said that all respiration is cutaneous, since whatever be the variety in form of the special respiratory apparatus, it essentially consists in a prolongation and development of the integument, the cutaneous development being outwards in the branchial forms, and inwards in the tracheal and pulmonary forms of the respiratory apparatus.

There is great variety in the form of the special respiratory apparatus in different animals, the apparatus being beautifully adapted to the habits of the animal. In each species, as the habits of the individual change during its progressive development from the embryo to the perfect condition, one kind of respiratory apparatus is exchanged for another to meet the change in the habits of the species. If, from some peculiar circumstances, those habits do not undergo the usual change, the form of the respiratory apparatus remains unaltered; and if, on the other hand, the habits be prematurely changed, a fresh form is prematurely substituted for the former one.

Among the inhabitants of water, some, as the holothuria, respire by means of ramified tubes; the water being alternately admitted into and expelled from the respiratory tubes. Others, as the annelida, possess, on their exterior, ramified branchial tufts generally, but, as Dr. T. Williams has shown, not always covered with cilia, and connected with the organs of locomotion, the respiration being thus increased when locomotion is excited. The circulation in the different species is peculiarly and beautifully adapted to the various modifications of the respiratory apparatus. Others, as the mollusca, possess either a highly vascular mantle or pouch, or highy vascular branchial plates, covered with cilia; in these the aerated water is usually renewed by the motion of the cilia; in all of them the supply of fresh water is augmented by the movements of the animal. In the highest of them,—the cuttle fish,—the alternate renewal and removal of the water is secured by the alternate expansion and contraction of a special branchial chamber. In the mollusca, the action of the heart sends the blood first through the systemic capillaries, thence through the

systemic veins to the branchiæ, and thence through the branchial veins to the heart. The cuttle fish is, in addition, supplied with special branchial hearts. Others, again, as the fishes, have subdivided branchiæ, devoid of cilia, occupying branchial chambers, the blood to which is sent directly from the heart; the renewal of the water is secured by the opening and closure of the mouth and opercula. Finally, certain amphibia, as the siren, possess ramified branchiæ, exposed externally, and covered with cilia, the motion of which secures the renewal of fresh water. These, like the fish, possess a branchial heart, but the heart sends its blood simultaneously to the branchiæ, the lungs, and the system.

All these animals can renew the supply of water over the branchiæ. The exposed branchiæ of the branchial amphibia, the mollusca, and the annelida, being destitute either of independent motion or of mechanical adjustment to remove and renew the water, are supplied with cilia, which, being in continual motion, cause constant currents of fresh water to wash the gills. How far the motion of the cilia may be augmented or diminished, according to the necessity for increased or diminished respiration, I know not, but the energy of the circulation, and therefore of the respiration, can be and is increased or diminished in these beings to meet their varying wants.

The higher crustacea and fishes are supplied either with moveable branchiæ or with a special apparatus for renewing the water, and their branchiæ are devoid of cilia. It is manifest that those gills which are covered with cilia cannot absorb the oxygen from the water so readily as those which are devoid of cilia, and that the aquatic respiration of the higher crustacea and of fishes is more perfect than that of the annelida, the mollusca, and the branchial amphibia. The active energetic habits of the crustacea and of fishes correspond with the higher development of their respiratory organs, while the comparatively sluggish life of the mollusca and the branchial amphibia is in keeping with the lower development of their respiratory organs. In harmony with their higher energies, the former class also possess a greater power of varying the amount of respiration; if they be torpid from cold or excessive heat, their respiratory mechanism is at a stand-still; but if they be excited by a due temperature or by exertion, then their respiratory movements are increased in exact proportion to the

increased excitement. These classes enjoy, in fact, greater vital range, owing to the greater variety of their respiratory functions, and in connection with the greater vigour which they exert in capturing their prey.

The increasing energy of the various species in the ascending scale of crustacea and of fishes is proportioned to the increasing development of the respiratory apparatus and functions. Among crustacea, the lower and feebler forms are devoid of any special respiratory apparatus, while the higher forms, as the crab and lobster, possess a highly developed branchial apparatus. Among fishes, the lower forms have a temperature equal to or only from 1° to 2° above that of the surrounding medium, while, according to Dr. Davy, the bonito possesses a temperature 19° above that of the sea.

There are two great varieties in the form of the respiratory apparatus of air-breathing animals,—tracheæ or air tubes, minutely sub-divided; and pulmonary air-sacs, simple or minutely sub-divided.

Insects, and some of the arachnida, are supplied with a complete system of ramified tracheæ, which convey the air through their infinite sub-divisions directly to every part of the organism. The circulation of insects is imperfect. The rapid and complete double circulation in the higher animals, conducting the blood from the system to the respiratory organs, and from the respiratory organs back again over the whole system, is not required by insects, endowed, as they are, with perfect respiratory channels diffused through every, the minutest, part of the organism. The respiratory system of insects may, in one sense, be said to be the most perfect of all respiratory systems, inasmuch as, from its universal distribution, that great function of respiration, the production of animal heat, can be performed more quickly by insects than by any other class of beings, however high in the scale of organization. For instance, when the thermometer stood at 17°.5 in the air, the temperature of a hive was raised in sixteen minutes from 30° to 70°, by merely tapping the exterior of the hive, and so arousing the bees; while, when M. Saissy roused a hedgehog from profound hybernation, it did not awake properly for two hours, when its temperature had only risen from 39° to 54°, and it was not until a lapse of four hours that it had attained the temperature of 89.°5. The extraordinary rapidity with which insects, especially bees, can raise their

temperature, is in harmony with the rapidity with which they can pass from a state of rest to a state of the highest and most sustained activity, and with the rapidity with which it is required that one nurse bee after another shall raise its temperature, while brooding over the cell of the young bee just before it is hatched. The circulatory apparatus of insects is adapted to the respiratory apparatus. The blood moves rather in channels than in vessels, the tracheæ and the various structures being bathed in the blood, which is propelled slowly forwards by the long many-valved dorsal heart, and by muscular movements, which, taking effect in each limb, give to each member a partial special circulation of its own. This circulation is at once systemic and respiratory.

Although the tracheal form of respiratory apparatus, branched as it is throughout the system of the insect, and capable of rapidly and extensively raising its temperature, constitutes that interesting little creature, the bee, the type of respiratory power; yet the pulmonary form of respiratory apparatus, in its highest organization, is the most compact, concentrated, and highly-developed.

There is every grade of pulmonary respiratory apparatus, from the simple sac of the snail to the infinitely sub-divided lung of the mammal.

In the snail, the air-sac on one side of the body is opened by the circular retraction of its mouth and walls, and closed by their contraction. The heart is systemic, the blood being sent first through the system and then through the walls of the air-sac.

In spiders and scorpions, the tracheæ of insects are replaced by pulmonary sacs, sub-divided by laminæ into cells, with gill-like partitions; while the heart, long and many-valved in the insect, is concentrated into one cavity, which sends the blood over the system, and then in whole or part over the air-sacs.

Amphibia, reptiles, birds, and mammals, are all endowed with lungs.

In the frog there is one large sac, the walls of which are honey-combed with highly vascular shallow cells.

In the serpent the lung is in part a mere membranous air-sac, in part its walls are cellular, as in the frog.

In the turtle the cells extend so as to fill up the lung.

In the mammalia the air-cells are minute and universally diffused, being constituted of very fine capillaries. In the porpoise and

whale the cells fill the whole lung, which is devoid of interlobular partitions. In the other mammalia fibrous partitions sub-divide the lungs into lobes and lobules.

In birds the sub-division of the capillaries are exceedingly minute, the lobules are long, and convoluted at the surface, the fibrous tissue is absent, and air-sacs communicating with the lungs are diffused through the system.

In all the pulmonary animals, from the pulmonary snail to the bird, the respiratory surface of the air-cells is devoid of cilia. In the vertebrate pulmonary animals the air passages are lined by columnar epithelium, tipped with cilia. The cilia never extend into the air-cells; indeed, if they did, seated as they are on columnar epithelium, they would impede the aeration of the blood, completely fill the air-cells, and solidify the lungs.

The circulatory apparatus is developed, in the ascending scale of pulmonary animals, in proportion and relation to the development of the respiratory apparatus.

In the frog a common ventricle receives the blood from a pulmonic and a systemic auricle and propels it simultaneously to the system and the lungs. When the respiration is entirely cutaneous, the systemic auricle alone receives the aerated blood.

In the turtle the ventricle is so partitioned that the greater part of the venous blood passes to the lungs, while the greater part of the arterial blood is told off to the system.

In the crocodile the heart is double, one side systemic, the other pulmonic, but owing to a peculiar arrangement of the great vessels, a part of the venous blood is sent to the system.

In birds and mammalia a complete double circulation is established.

Movements of Respiration in the Lung-breathing Animals.

The frog, which is destitute of ribs, distends its lungs gradually, by a frequent deglutition of air, and empties them at once by the action of the abdominal muscles.

The serpent inspires by elevating its ribs, which are altogether vertebral, and by separating the opposite ribs from each other, so as to deepen and widen the pulmonary cavity.

The bird has a sternum and sternal ribs, as well as a vertebral column and vertebral ribs, which so combine their movements as

to widen and deepen the chest during inspiration, and to contract it during expiration. The diaphragm is only rudimentary.

The mammalia possess a large and efficient diaphragm, which, at each inspiration, lengthens the lungs to a considerable extent, they, therefore, require a totally different arrangement in the bony framework of the chest from that which obtains in birds.

In mammalia the upper part of the chest is roofed over by the progressively narrowing series of ribs and cartilages which, with the sternum, encase the lungs, and by the strong muscles which raise the first ribs. If the upper part of the chest were not thus covered in, but were left exposed in front without a strong, protecting, and expanding bony covering, as is the case in birds, the upper portion of the lungs would collapse and be pushed downwards and backwards under atmospheric pressure, when the whole lung is lengthened and drawn from above downwards by the descending movement of the diaphragm. The movements of the upper ribs and diaphragm are so beautifully adapted to each other that when that muscle lengthens the lungs downwards the upper ribs lengthen the lungs upwards and expand them forwards.

In mammalia, while the upper ribs meet in front through the medium of the cartilages and the sternum, the space between the lower ribs of opposite sides is open in front owing to their cartilages being unattached. The opposite arrangement obtains in birds, for while in them the space between the upper ribs of opposite sides is open in front from the absence of corresponding sternal ribs, the space between the lower ribs is closed in front, through the medium of corresponding sternal ribs and the sternum. Thus in mammalia the upper part of the lung is protected by a bony covering, while the abdomen is exposed; whereas in birds the upper part of the lung is unprotected, while the abdomen is shielded by a bony covering.

Owing to the arrangement of the ribs rendered necessary by the presence of an efficient diaphragm, the relative movements of the upper ribs to each other differ from those of the lower ribs; for while the upper ribs converge during inspiration, the lower ribs diverge; while the upper ribs expand the upper lobes upwards, forwards, and sideways, the diaphragm and the lower ribs expand the lower lobes downwards, backwards, and sideways.

In conformity with the different relative movement of the upper

and the lower ribs the intercostal muscles between the upper ribs have a different action from those between the lower ribs. While the external and internal intercostals between the uppermost of the thoracic ribs are in great part inspiratory, the external and internal intercostals between the lower diaphragmatic ribs are in great part expiratory. The intermediate ribs are raised during inspiration by the external intercostals, and are depressed during expiration by the internal intercostals. This action of the external and internal intercostals is the natural action of those muscles when no modifying influence is introduced to change the relative form and movements of the ribs; it is the same action which obtains throughout in the serpent and the bird, all the external intercostals being in them inspiratory, and all the internal intercostals expiratory.

I find that in the mammalia the relative size of the anterior and posterior lobes of the lungs, the relative extent of movement of the anterior or thoracic ribs, and of the posterior or diaphragmatic ribs and diaphragm, are regulated by the position and function of the fore-limbs.

In the herbivora, the animal, when grazing, rests firmly on the fore-limbs; it is, therefore, important that the scapulæ on each side of the ribs should not be widely separated at each inspiration; consequently the chest is narrow and deep, the anterior or thoracic ribs are strong, and have but a limited range of motion, the anterior lobes are small, the posterior lobes are large, the diaphragm is extensive in size and motion, and the posterior or diaphragmatic ribs are comparatively numerous, and have great play during respiration. The horse, which of all animals requires the most powerful support and use in the fore-limbs, is the type of this class.

In the porpoise, the seal, the kangaroo, the bat, and in man, the fore-limbs, which are not used to support the animal, have complete freedom of motion, and their varying separation does not interfere with their action, whether in swimming, flying, or prehension; consequently the chest is broad and full, the anterior or thoracic ribs are slender and long, and have an extensive range of motion, the anterior lobes are large, the posterior lobes are not, relatively to the anterior, so large as in the herbivora, the diaphragm is not so extensive in size and motion, and the posterior or diaphragmatic ribs are fewer in number, and have less play during respiration. The porpoise may be considered the type of this class.

THE CAUSES AND MEANS WHICH EXCITE AND INFLUENCE RESPIRATION.

Excitement of Respiration by External Stimulus.

The first shock of a cold shower bath excites a deep involuntary and almost convulsive respiration. In like manner, if cold water be dashed suddenly on the face or body; if the hands or feet be suddenly dipped into cold water; if the body be suddenly plunged into a cold or a warm bath, a deep quick inspiration is immediately induced.

Dr. Marshall Hall relates that Dr. Heming witnessed the following interesting fact:—An infant just born, and covered by the bed clothes, did not breathe. After waiting a few seconds, Dr. Heming proposed to himself to adopt some measure for this asphyxia, and lifted up the bed clothes. The contact of the cool atmosphere instantly excited an act of inspiration.

Dr. Hartley, in his "Observations on Man," remarks that vigorous impressions from the cold air and cold handling of the midwife may excite the strong respiration and crying which take place upon the birth ordinarily. When the new-born child fails to respire freely the methods used to make it do so are, applying volatiles to the nose, swinging the child to and fro, and other methods which excite the muscles to contraction by making strong impressions on the neighbouring sensory nerves.

Dr. Marshall Hall observes that in the very young kitten, even when asphyxiated to insensibility, every touch, contact, or slight blow—every jar of the table, any sudden impression of the external air, or that of a few drops of cold water—induces at once energetic reflex movements and acts of inspiration. The nostrils, the tail, the soles of the feet, the general surface, are all extremely susceptible, and in degree in the order mentioned.

In syncope, circulation and respiration are almost or altogether suspended; the dashing of cold water or the blowing of cold air on the surface usually excites a deep inspiration; the repeated renewal of the dashing excites again and again renewed deep inspirations, and at length leads to the restoration of consciousness, as is illustrated in cases given below. In laryngismus stridulus, and sometimes in the fits of hysteria, although the inspiratory muscles are acting with convulsive power, inspiration may be

altogether stopped by the closure of the glottis, owing to the forcible contact of the vocal chords. When cold water is dashed on the surface the vocal chords are immediately drawn asunder, and a deep inspiration follows.

In the epileptic fit, although the expiratory muscles are in violent convulsive action, the expiration cannot be performed owing to the closure of the glottis by the forcible contact of the vocal chords; if cold water be dashed upon the face and body, the vocal chords are usually drawn asunder, when an act of inspiration is excited, and the convulsion is interrupted; by the repetition of such excited acts of inspiration the fit is finally put an end to.

In all these instances the act of inspiration is excited through the reflex function of the nervous system—the sudden impression made on the skin stimulates the extremities of the incident nerves; the stimulus is conveyed by the incident nerves to the spinal nervous centre, and is thence transmitted back over the motor nerves of inspiration. That these repiratory movements are purely excito-motor, and performed without the intervention of sensation, in many of those instances in which the excited movements are most energetic, is proved by the ease with which remarkable movements of respiration were occasioned by stimulating the surface in cases of syncope, hysteria, and epilepsy, cases in which sensation was altogether absent, and was only restored after repeatedly stimulating the surface, and so inducing deep reflex inspirations again and again by exciting the incident nerves. In many of those instances in which consciousness was present, the movements were evidently excito-motor, and quite independent of sensation. In some instances, especially where deepened and quickened inspirations were excited in connexion with pain and with exalted sensation, there is reason to believe that reflex movements were excited by the sensation itself, conjointly perhaps with the excito-motor influence on the one hand, and independently of volition on the other; in many of these instances it would appear as if the excited inspiratory movements were at once both consensual and excito-motory.

It is to be observed, as a general rule, that wherever there are nerves with an incident or excito-motor function, there are there nerves with a sensory function. Whether the sensory and incident functions are blended in one nervous filament, or whether separate

sensory and incident filaments are blended in one nervous trunk, has not as yet been distinctly shown.

In considering the causes which excite respiration it is important to bear this in mind, that wherever a nerve exists possessing sensory functions, there a nerve exists possessing incident functions; wherever the nerves of sensation are numerous, there the incident nerves are numerous; and that wherever sensation is very exquisite, there the reflex functions of the true spinal system are very readily excited.

The extent to which the act of inspiration is excited by the application of a stimulant to the surface depends on the intensity of the stimulus, the extent of the surface, and also the impressibility of the part of the surface to which the stimulus is applied.

If the impression be sudden and powerful, and applied over a great extent of surface, or to a part of the surface supplied with many incident nerves, then the act of inspiration is deep, and all the inspiratory muscles are called into play. The nostrils are dilated, the mouth is opened, the fauces being widened, the glottis is extensively enlarged, the shoulders are much raised, the chest is expanded to a great extent, and the diaphragm descends considerably.

On the other hand, if the impression be slight, applied over a large extent of surface, or to a part of the surface supplied with only few incident nerves, then the act of inspiration is limited, the supplementary muscles are not called into play, the mouth is not opened, the nostrils are not dilated, and the glottis is only inconsiderably widened.

The stimulus exciting the inspiration is in every instance so distributed through the incident nerves and the spinal marrow, along the motor nerves, that the outer apertures, the mouth and nostrils, and the aperture at the glottis, are dilated in exact proportion to the expanding force exerted by the muscles of inspiration over the cavity of the chest.

The extent to which the apertures are dilated is, I repeat, in exact proportion to the force exerted by the respiratory muscles, and not necessarily in proportion to the extent to which the lungs are expanded. Indeed the external apertures dilate quite as much in those cases in which air cannot enter the lungs, and in those in which the whole of the inspired air passes through a large opening in the trachea, as they do when the inspired air enters wholly

through their external apertures. After opening the trachea in a dog I divided the vagi, and the inspirations were immediately performed with power by the whole of the inspiratory muscles; notwithstanding that the whole of the air entered through the divided trachea, the nostrils, mouth, and fauces were opened and dilated to the fullest extent, the head being at the same time thrown backwards so as to raise the upper jaw, and the same movements were excited when the opening into the trachea was closed. I observed a similar phenomenon in a man who, after laryngotomy, breathed entirely through a tube in the trachea; though no air entered the nostrils, yet they dilated with power at each inspiration.

This fact, that the muscles expanding the inspiratory apertures act even when no air can enter through those apertures, shows how perfectly in harmony with each other and with the extent of the cause exciting inspiration, are the various inspiratory muscles. The whole of those muscles are, in the instances alluded to, perfectly obedient to the influence stimulating their combined action to effect the common purpose of inspiration, and that, even although the action of a number of those muscles could not, under the circumstances, aid inspiration. This shows how completely respiration is usually automatic, that is to say, under the dominion of the excito-motor function of the nervous system, and withdrawn from under the dominion of the will, even when volition is active, unless the will be specially and energetically directed to the control of the respiratory movements; indeed, in the instances just referred to, even although the will could repress or modify the respiratory movements as a whole, I doubt whether it could repress any of those movements in part.

If cold water be dashed suddenly on the whole body, or if a man plunge into cold water, or into a hot bath, deep, energetic, often sobbing, almost convulsive respirations will be excited, even although the will should struggle to repress them. If the cold water be dashed upon the face only, the inspiration excited will be less energetic, but still the will can scarcely ever repress or control them. If the highly-sensitive nostril be alone stimulated, as for instance by the point of a feather, or by ammonia, or by snuff in a person unused to it, a deep inspiration will be excited, followed by sneezing, in spite of the will. In these instances the stimulus

was either intense, or was applied extensively, or to a surface highly sensitive, and possessing many highly impressible incident nerves, and the effect was an uncontrollable deep inspiration, the inspiration varying in depth, in proportion to the nature and suddenness of the stimulus, the extent of the surface stimulated, and the impressibility of the portion of surface stimulated.

If, when the person is conscious, cold water be dashed suddenly, but to a small extent, on the back, or if the feet or hands be dipped suddenly in cold water, an inspiration will be drawn, varying in depth in proportion to the stimulus and the excitability of the surface, but such inspiration is under control, and may be repressed by an exercise of the will.

In the instances given above, in which an inspiration was excited by stimulating the surface, the stimulus was instantaneously and suddenly applied, and the effect on the respiration was instantaneous and fleeting. The surface was stimulated, a deep inspiration was drawn, but, with the exception perhaps of the next few inspirations, respiration speedily resumed its ordinary character.

This is an illustration of the general law—that whenever a reflex movement is excited through a stimulus applied to an incident nerve, that movement is instantaneous in accession and short in duration. If any incident nerve be pinched an immediate reflex movement follows, but this movement soon ceases, even if the pinching be continued; if the same stimulus be withdrawn, and then again repeated, another similar reflex movement will be excited. This may be repeated again and again until the excitability of the incident nerve by that particular stimulus be exhausted.

If respiration be suspended, owing to the deprival of oxygen, or to the respiration of noxious gases, or of gases destitute of or deficient in oxygen, or by the action of poisons—provided the suspension of respiration have not lasted too long, or have not been occasioned by too extensive an influence from the noxious agent—respiration will frequently be stimulated to renewal by the mere exposure of the surface to the atmospheric air, with or without external warmth.

Sir Humphrey Davy performed the following experiments:—

A stout and healthy young cat, of four or five months, was introduced into a large jar of nitrous oxide. For ten or twelve

moments he remained perfectly quiet, and then began to make violent motions, throwing himself round the jar in every direction. In two minutes he appeared quite exhausted, and sunk quietly to the bottom of the jar. The heart beat with extreme violence, and there was a strong and quick pulsation of the carotids. In about three minutes the animal revived, and panted very much; but still continued to lie on his side. His inspirations then became longer and deeper, and he sometimes uttered very feeble cries. In four minutes the pulsations of the heart appeared quicker and feebler; his inspirations were at long intervals and very irregular. In five minutes the pulse was hardly perceptible; he made no motions, and appeared wholly senseless. After five minutes and a quarter he was taken out and exposed to the atmosphere before a warm fire. In a few seconds he began to move, and to take deep inspirations. In eight or ten minutes he was able to walk; and in about half an hour he was almost completely recovered.

A rabbit was immerged in hydrogen for nearly half a minute, and was restored to the atmosphere apparently inanimate. In less than a minute he began to breathe and to utter a feeble noise; in two minutes he was able to walk, and in less than three minutes appeared perfectly recovered.

A small water-lizard was introduced into nitrous oxide gas. In two or three minutes it began to make violent motions, appeared very uneasy, and rolled about the jar in every direction, sometimes attempting to climb to the top of it. At the end of twelve minutes it was lying on its back seemingly dead, but on agitating the jar he moved a little; at the end of fifteen minutes he did did not move on agitation, and his paws were resting on his belly. He was now taken out stiff and apparently lifeless, but after being exposed to the atmosphere for three or four minutes, he took an inspiration, and moved his head a little; he then raised the end of his tail, though the middle of it was still stiff, and did not bend when touched. His legs remained close to his side, and were apparently useless; but on pricking them with the point of a lancet they became convulsed. After being introduced into shallow water he was able to crawl in a quarter of an hour, though his motions were very irregular. In an hour he was quite well.

These experiments show that an animal, either warm or cold blooded, after ceasing to breathe when in a noxious gas, being

apparently lifeless, may have its respiration again excited by the simple stimulus of exposure to atmospheric air. The stimulus is here applied externally to the skin, not internally to the lungs, nor yet to the brain nor spinal marrow, but directly to the skin, and through the skin to the incident nerves; their excitability, exhausted by the noxious gas circulating in the blood, is first roused by the atmospheric air, and then they are excited by the air, so as to induce reflex acts of respiration.

Dr. Goodwin relates the following interesting experiment, in which, after submersion, exposure to the air re-excited respirations:—

"I confined a large toad on a plate of metal; I then removed a part of the sternum, and his heart and lungs were exposed to view. The lungs were then filled with air; the blood in the pulmonary veins was florid, and the heart contracted forty-four times in a minute. In this state he was immersed in a small quantity of transparent water. When he had remained in the water fifteen minutes, the blood in the lungs began to put on a dark colour, and the contractions of the heart were diminished to thirty. In fifteen minutes more the dark colour of the blood was increased, and the contractions of the heart were eighteen. The animal now made several struggles to relieve itself, and threw some air out of its lungs; but the pulmonary blood becoming still more dark-coloured the contractions of the heart were diminished still further; and in forty minutes more they ceased, although the sinus venosus and auricle, and the trunk of the vena cava were filled with black blood. The animal was now removed from the water, without any signs of life; but before the expiration of two minutes he opened his mouth and took a large quantity of fresh air into his lungs. Soon after he emptied them almost entirely, and this was repeated several times. During the process the blood in the pulmonary veins began to be florid, and the heart to renew its contractions; and in fifteen minutes from the first inflation the contractions of the heart were thirty-five, all the functions were recovered, and he walked about without any expressions of uneasiness."

In this interesting experiment it is possible that the exposure of the lungs, as well as the skin, to the atmospheric air may have had some influence in exciting the renewal of the respiration.

In the following experiment, performed by Dr. W. F. Edwards,

and related in "Dr. Hodgkin's Translation," the skin alone was exposed to the action of the air, after submersion in water:—

"If a frog, deprived of its heart, and immersed in water, be drawn out and exposed to the air at the moment when all signs of life have disappeared, it immediately begins to recover. If it be again plunged in water all appearance of life instantly ceases; and it may thus be made several times alternately to lose and recover its motion and sensibility. This confirms, in a striking manner, the vivifying effect of air and the deleterious effect of water on the nervous system."

A similar experiment was performed by Dr. Marshall Hall. He divided, in a frog, the spinal marrow, near the cranium, and left it immersed in water:—the excito-motor power seemed to have ceased; there was no respiration, no movement on irritating the toes; on being removed from the water, and placed in the free open air, respiration and the excited reflex movements were gradually restored.

Professor Müller illustrates this subject by some experiments performed by himself and Professor Bergmann:—

"I kept a frog during four hours in hydrogen; at the end of that period it was apparently dead, the heart's pulsation ceased for minutes at a time; but the animal revived when restored to the air."

"The arterial blood is very beautifully shown to be the cause of the continuance of the respiratory movements throughout life, by my experiments on frogs, in which I made the animals breathe for several hours in hydrogen; after a time respiration ceased, although life was not extinct. For a time the respiratory movements were renewed when the vessel in which the animals were included was agitated; but, after a longer period had elapsed, this was no longer the case. If, after being thus confined in hydrogen for two or three hours, the frogs are taken out and exposed to the atmosphere, they appear perfectly dead; not the least sign of motion or sensation is observable in them. The heart being laid bare, if it is found to have ceased to beat, the animal will not revive. If it still beats, though at intervals of half a minute or a minute, the frog will generally recover without any external stimuli being applied, merely from the gradual oxidation of the blood in the vessels of the lungs, the want of which arterialization was the cause of the

asphyxia. The blood, impregnated with oxygen, however slow the action of the heart, must at length reach the brain and the medulla oblongata, which then begins again to emit nervous influence. The first signs of the revival of a frog, which lies quite motionless, is the retraction of the extremities when the skin is pinched; after a short time it is seen to respire at longer intervals, and in a few hours is quite lively. The cause, therefore, of the continued action of the medulla oblongata in determining the respiratory muscles to action is the arterial blood."

I have given the whole quotation in justice to Professor Müller, remarking at the same time, that while we accept the facts, we cannot accept the opinions with regard to the aeration of the blood in the lungs and in the medulla being the cause of the renewed inspiration. Dr. Baly justly remarks upon this experiment:—"It appears to the translator to be more probable that the blood was arterialized in this experiment chiefly through the medium of the skin; for we know that frogs will live many hours after their lungs are extirpated; while, immersed in oil, they die in less than an hour; and in an asphyxated frog the entrance of air to the lungs, and its renewal, must be very limited."

In Dr. Edwards's experiment the frog was deprived of the signs of life in water, but recovered its motion and sensibility when exposed to the air. Here the heart had been previously cut out, consequently the renewal of life was strictly due to the action of the air on the cutaneous nerves and capillaries.

I conclude that in all the above instances the renewal of motion on pinching, and the renewal of respiration, was due to the renewal of the excitability of the cutaneous incident nerves; the stimulus of pinching the surface, previously without effect, then excited reflex motion, and the stimulus of the air, applied to the different cutaneous nerves, then excited reflex acts of respiration.

The experiments detailed by Dr. Alston in the Medical Essays, show that after a frog has been deprived of life, to all appearance, by opium, it may possibly recover by the mere exposure to the atmosphere. In those experiments he inserted opium in solution into the stomach of the frog:—

"This experiment we frequently repeated, and it had always the same appearance and event. The recovery, however, of one of the frogs, which for a considerable time seemed to be dead, is not to be

omitted. My friend and I one evening killed, as before, a couple of frogs with opium; one of them, which was the strongest, I laid half in water, on a tile in the bottom of the water-pot, that if it recovered it might sit wet or dry, as it liked best; the other I left on the earth, dry, under a hedge. Next morning, when I returned to the garden, I found the one under the hedge dead, as I left it, but the other in the water-pot was alive, and appeared to be in perfect health.

Taking the above observations on the vivifying effect of exposure to the atmosphere, after respiration and animation were suspended, and looking on them in a group and as a whole, we may conclude that in those instances the renewed respiration was excited reflexly by the stimulus which the incident nerves of the skin received from the atmosphere acting on the tissue of the skin and aerating the blood in the capillaries.

Effects of the Narcotic Poisons on Respiration, through the medium of the Incident Nerves.

The effects of the narcotic poisons, and the treatment of those effects, afford an interesting practical illustration of the effect which the excito-motor phenomena, stimulated at the surface, have in exciting and influencing respiration.

The narcotic poisons, though properly grouped in one class, differ exceedingly in their effect on the system. The characteristic effect of some, as belladonna and stramonium, is upon the brain; that of others, as chloroform and ether, is upon the brain and the spinal marrow; while that of others, as prussic acid, is more markedly upon the spinal marrow and the incident nerves. While the characteristic effect of each of these groups is upon the parts of the nervous system just indicated, it may be said that each of them acts more or less both upon the brain and spinal marrow as central organs, and on the nerves at their periphery, both in their incident and sensory functions. I confine myself at this place to the effect which all these poisons have on the afferent, especially the cutaneous nerves at their periphery, through the medium of the blood circulating in the superficial capillaries.

The influence of opium on the capillary circulation, and on the afferent nerves is shown in the following experiment, which is a modification of that made by Dr. Alston, just referred to:—

I attached a frog to Mr. Goadby's frog-holder, plunged the left leg

into a test tube containing a watery solution of opium, and the right leg into one containing water. The tubes were so arranged that they could be withdrawn, and either web placed under the microscope without disturbing the frog.

Before the immersion of the left leg in the solution of opium the circulation was very rapid; the corpuscles in the arteries moved so quickly that they could scarcely be distinguished; those in the veins and the large capillaries moved rapidly, while those in the small capillaries moved slowly. After an immersion of ten minutes the motion of the blood in the smaller capillaries of the left leg was quickened, and the blood circulated through many capillaries previously devoid of corpuscles. The movement of the blood in the arteries and veins was less rapid. The circulation in the right leg was unaltered.

After a further immersion of the left leg in the solution of opium for forty minutes that leg was swollen, being, evidently to the eye, more vascular than the right. All the capillaries were now much enlarged, several corpuscles moving slowly, side by side, through capillaries that were previously empty. The blood moved much more slowly than before, both in the arteries and the veins.

The circulation in the right leg was now very perceptibly modified, and, as nearly as could be observed, to the same extent as that in the left leg, after it had been immersed in the solution of opium for ten minutes.

The effect on the excito-motor phenomena was marked; whenever the skin was touched, either on the left or right leg, the frog cried out in a peculiar manner, the creature being severely convulsed. The skin was touched repeatedly and in rapid succession, with the invariable effect of producing renewed convulsions, which became less and less strong each time they were excited. At length the convulsions could no longer be excited by touching the left leg, and after a time they ceased also to be excitable in the right leg. After a little rest the convulsions could again be excited.

After re-immersion for an hour and a half, the frog being then perfectly relaxed in all its limbs, quick feeble tetanic spasms of both limbs were excited by the slightest motion, by walking across the room, by touching the microscope, or by touching the skin of either leg. These convulsions ceased after the legs had been touched repeatedly and in rapid succession; the left leg first lost its

excitability and then the right. The convulsive movements were slighter in the left leg than elsewhere.

It was found, during this observation, that the frog was quite unconscious, and had ceased to breathe.

The capillaries were now very much enlarged in the left leg, being greatly distended and almost blocked up with the accumulation of blood corpuscles, the motion of which was but just perceptible. The movement of the blood in the arteries and veins was exceedingly sluggish. The right leg was similarly affected, but the capillaries were not so much distended, and the circulation was not so slow as in the left leg. The circulation became progressively slower. The convulsions, after a time, were no longer excitable.

About four hours after the first immersion of the leg in the solution of opium, the heart was exposed, pulsating slowly, emptying itself on each contraction, and receiving and sending out but little blood. After the heart was cut out the movement of blood in both webs continued, though it was very sluggish, and in the left leg was only observable in the large artery and vein.

This experiment shows that under the influence of opium the circulation in the capillaries and great vessels becomes obstructed, the quantity of blood in them being increased. This is unequivocally due to the local action of the poison, absorbed through the skin locally, and conveyed by the blood generally, produeing relaxation of the walls of the vessels, enlargement of the capillaries, and inereased amount but slower motion of the blood in all the vessels,—in faet, general congestion. Under the influence of the poison, applied locally, and conveyed through the blood, the incident nerves are at first morbidly excitable, but finally their exeitability is exhausted.

The following instructive experiment is described by Müller:—"I dissected out the ischiadic nerve in toads, and left the leg connected to the body by this nerve only, whieh, together with the leg, I then immersed in a strong watery solution of opium; in a short time the nerves and muscles lost all susceptibility of the influence of galvanic or chemical stimuli." It is manifest that in this experiment the excitability of the incident nerves was destroyed, as well as that of the motor nerves and the museles, since no reflex actions were excited by electricity, although the nervous eommunieation with the spinal marrow, through the medium of the ischiadic nerve, was uninjured.

M. Chossat injected a solution of opium into the veins of a dog, and noticed the effect on the pulse, the respiration, and the temperature. The details are given in the table at p. 186. During the first hour the respiration and the pulse rose respectively from 8 and 102 in the minute, to 20 and 173. The respiration, after the first hour, gradually fell, hour by hour, to 15, 11, and 9, until, at the seventh hour, they were below the original number. They continued falling steadily, and during the last hour they were between 2 and 3 in the minute.

In man the excito-motor phenomena are not so markedly increased in excitability by the narcotic poisons, owing to the reflex functions being more strongly controlled by the brain in man than in the lower animals. While opium always excites tetaniform convulsions in the lower animals, it seldom excites convulsions in man. A much larger proportion of children are affected with convulsions, when under the poisonous action of opium, than of adults, because of the superior control exercised by the brain over the reflex functions in the adult than in the child.

The effects of opium on the human subject is thus well described by Whytt:—"A child of five years of age, having, at seven o'clock in the evening, swallowed, by mistake, about a drachm and a half of liquid *laudanum*, soon became merry, and laughed, then delirious, and in half an hour was seized with a sleepiness and stupor; at ten her breathing was high, with a snoring noise, her pulse full and equal, though slow; she could not be fully awaked, but looked up a little, and seemed to be sensible of pain, when severely pinched: about eleven her face became pale, her eyes fixed and glazed, and her breathing would often gradually decrease, and at last stop for near a minute; then it began again with a very deep inspiration and sighing. At first, when the breathing began to be thus interrupted, the intervals were shorter, but became gradually longer till the patient died. While the motions of respiration were decreasing, the pulse was smaller; and when they were altogether stopt it was very weak and slow, but equable, and without intermissions: when respiration began to be renewed the pulse recovered its strength and became less slow."

It is of the more importance to preserve this case in our literature, since, happily, no such opportunity of observing the undisturbed phenomena of the effects of opium on the respiration and

circulation can again occur, now that the treatment of such cases is so well understood.

I conclude that, under the influence of opium, the respirations are at first quicker and fuller, owing to the increased excitability of the incident nerves of the surface—the respirations being excited by a reflex action from the incident nerves, those nerves being stimulated by the opium in the blood circulating in the systemic capillaries. After a time the increased excitability gives place to diminished and exhausted excitability of the incident nerves, and consequent diminution and cessation of respiration. Farther proofs of this position will be afforded in considering the treatment of narcotic poisoning.

All the narcotic poisons possess, like opium, the property of causing relaxation of the capillaries, and increase of blood and obstruction to the circulation in the capillaries, arteries, and veins. Under the influence of belladonna and stramonium the face is frequently rendered red, and it has been noticed to be bloated or swollen under the action of cicuta virosa, aconitum napellus, œnanthe crocata, and strychnia. Professor Simpson and Mr. Nunnelly have observed that chloroform applied locally, either as a liquid or a vapour, causes great reddening of the surface. Mr. Nunnelly observed that the mouth was rendered intensely red by the administration of prussic acid.

Tobacco and digitalis cause such excessive congestion of the pulmonic capillaries that but little blood can be sent round through the lungs to the left side of the heart and the system; the right cavities are, consequently, enormously distended, and, owing to the distention, those cavities cease to contract. The systemic vessels are scarcely supplied with blood, owing to the detention of the blood in the lungs, and the arrest of the heart's action. The important experiments of Dr. Blake, made with the hœmodynamometer, show how remarkably these poisons obstruct the circulation through the systemic capillaries.

These instances show that when a poison enters the blood, the poisoned blood accumulates to an unusual extent in the systemic capillaries, unless the obstruction in the pulmonic capillaries be excessive, and that the poison is thus presented with an accumulating effect to the extremities of the afferent nerves.

The effect of ether and chloroform on the respirations was

observed in a very instructive manner in an experiment on a dog, which I performed, with the valuable aid of Dr. Snow and Mr. Marshall.

The ether and chloroform were administered by Dr. Snow from a balloon impregnated with the vapour, and adapted to the almost divided trachea. All stimulus to the larynx was thus avoided, and the effect on the respirations, at first of the application of the agent to the mucous membrane of the lungs, and then of its diffusion over the whole system, was observed.

When ether was administered the respirations were not accelerated at first; in 10 or 15 seconds they increased in number; on withdrawing the ether the increased rate continued for about 10 or 15 seconds, when the respirations began gradually to diminish. The chloroform was administered with the same general effect.

The following observations of the number of respirations during each successive 10 seconds were made on the renewed application of chloroform.

During the first 10 seconds that the chloroform was readministered there were 10 inspirations; during every successive 10 seconds there were respectively 12, 14, 13, 14, 16, 17, and 19 respirations; after a lapse of about 40 seconds, there were, during successive 10 seconds, 16 and 20. When the bladder containing chloroform was withdrawn, the rapid respirations continued without material change, 19 in 10 seconds. When the respirations were at this rapid rate, acts of deglutition, whether automatic, or excited by stimulating the pharynx through the larynx, caused complete temporary suspension of respiration. After this the respirations were 17, 20, and 20, in 10 seconds. After two more minutes (it was then 21 minutes past 12 o'clock) the respirations fell to 14 in 10 seconds.

	No. of respirations in ten seconds.
At 12 h. 23 min. the number of respirations in 10 seconds was from ...	13 to 10.
12 h. 24 min. ,, ,,	12 to 13.
12 h. 25 min. ,, ,,	12.
12 h. 26 min. There was now a short renewal of the inhalation of chloroform. The number of respirations in ten seconds was unchanged, being still	12.
At 12 h. 27 min. the number of respirations in 10 seconds was	11.
12 h. 28 min. ,, ,,	8.
12 h. 42 min. ,, ,, from	$6\frac{1}{2}$ to 5.

It was evidenced from this administration, as from those made previously, that the increased number of inspirations did not take place immediately after presenting the vapour to the lungs, but that it took place gradually after the vapour had entered the circulation for a sufficient length of time to diffuse itself through the medium of the blood over the system, and so to excite everywhere the incident nerves of the system.

Just before the division of the vagus, the respirations were 30 to 39 in the minute. They had been about 20 in the minute before the experiment commenced.

At 12 h. 47 min.	the right vagus was divided, and the number of respirations fell immediately to	10 in the minute.
	All the inspirations, which were previously quiet, (the mouth being unopened, the nostrils undilated,) were now, and continued to be, performed with unusual energy. The nostrils dilated, the mouth gaped widely, the head being thrown back so as to raise the upper jaw, the fauces were dilated, and all the inspiratory muscles acted with great vigour.	
At 12 h. 51 min.	the number of respirations was	8½ in the minute.
12 h. 57 min.	both vagi were divided, when the respirations fell to	6 in the minute,
	and they continued to be performed steadily at the rate of 6 in the minute, even when the dog was disturbed and excited.	
At 1 h. 39 min.	a sponge, saturated with ether, was applied to the opening in the trachea; during the first minute the inspirations were	6 in the minute.
At 1 h. 40 min.	the respirations were	7 in the minute.
1 h. 41 min.	the respirations were	7 in the minute.
1 h. 42 min.	the respirations were	7 in the minute.
1 h. 43 min.	the sponge was removed, the respirations were	8 in the minute.
1 h. 46 min.	the sponge, saturated with ether, was re-applied; the number of respirations was	7 in the minute.
At 1 h. 47 min.	the respirations were	9 in the minute.
1 h. 48 min.	the respirations were	9 in the minute.
1 h. 49 min.	the respirations were	9 in the minute.
1 h. 50 min.	the respirations were	6 in 38 seconds.
1 h. 51 min.	the sponge was withdrawn; the respirations were still	9 in the minute.
	The repeated renewal and the final removal of the sponge caused no difference in the number of respirations	9 to 9½ in the min.

At 2 h. 7 min., when the dog was standing, the respirations rose to	10	in the minute.
After the dog had been moving about the respirations were	11	in the minute.
At 2 h. 12 min. chloroform was administered. The respirations were then from	8 to 9	in the min.
2 h. 13 min. the respirations were from	8 to 9	in the min.
2 h. 14 min. the respirations were	18	in the minute.
2 h. 15 min. the respirations were	30	in the minute.
The mouth no longer opened wide during each inspiration, the respirations being apparently natural. The chloroform was withdrawn about this time.		
At 2 h. 18 min. 7 respirations in 15 seconds, or at the rate of	28	in the minute.
2 h. 21 min., after the dog was subjected to excitement, there were 16 respirations in 10 seconds, or at the rate of	96	in the minute.
On nearly closing the trachea, the gaspings were renewed, but they ceased after about a minute.		
At 2 h. 25 min. 4 respirations in 15 seconds, or at the rate of	16	in the minute.
2 h. 29 min. 3 respirations in 15 seconds, or at the rate of	12	in the minute.
3 h. 29½ min. 5 respirations in 30 seconds, or at the rate of	10	in the minute.
After the administration of the chloroform, it was found that the reflex functions were very excitable, muscular movements of the limbs being easily and indeed constantly excited, by slight external irritation.		
At 2 h. 34 min. 25 respirations in 15 seconds, or at the rate of	100	in the minute.
2 h. 35 min. 10 respirations in 10 seconds, or at the rate of	60	in the minute.
2 h. 37 min. the gaspings were renewed.		

The conditions which preceded the rapid increase just stated are not mentioned. The experiment was shortly afterwards put an end to by the rapid and fatal administration of chloroform; the respiration ceased; the heart continued beating. About 30 or 60 seconds after regular respiration had ceased, deep inspirations with gaspings were taken; the heart's impulse was no longer perceptible.

From this experiment we see that after the division of the vagi ether increased the respirations slightly, although no reflex influence from the incident nerves of the lungs could have been transmitted through the medulla oblongata. Under the influence of chloroform the respirations rose from 10 to 30 in the minute. After this, movements on the part of the animal, and obstruction to respiration through the trachea, quickened the respirations exceedingly, so that

they were about 90 in a minute; while previously to the administration of chloroform, but after the division of the vagi, and after the administration of ether, the respiration only rose, during exertion, from 9 or 10 in the minute to 11.

It is to be observed that the excito-motor functions were abnormally excitable when the respirations were so much quickened under the influence of chloroform.

At a later period, when the chloroform was pushed, so as to produce diminution and cessation of the respiration, the excito-motor functions were no longer capable of being stimulated by external impressions, though the muscles could be induced to contract by the direct action of electro-magnetism, or by such action transmitted through the motor nerves. In fact the excito-motor nervous arc was broken, not on the reflex or motor side, but on the incident or excitor side.

Under the influence of most of the narcotic poisons, the respirations are at first accelerated and panting, then laboured and slow, and then fetched with increasing intervals, until they finally cease.

The effect of ether, chloroform, and alcohol, on the respiration, has been just illustrated.

Sir Humphrey Davy's experiment, related at p. 209, shows that when an animal is immersed in nitrous oxide respiration is first accelerated, then retarded, and finally abolished.

Mr. Nunnelly put a cat into a jar containing one part in four of common coal gas; in two minutes she was convulsed for 30 seconds, then became still and insensible, with the respiration quick, then irregular and slow; at three minutes and a half it nearly ceased for a minute; at four minutes and a half she breathed once or twice.

Sir Benjamin Brodie applied a drop of the essential oil of bitter almonds to the tongue of a young cat. She was instantly seized with violent convulsions; then lay on one side motionless, insensible, and breathing in a hurried manner; the respirations became laboured, took place at longer and longer intervals, and at the end of five minutes from the application of the poison had entirely ceased.

The same distinguished physiologist applied less than a drop of the empyreumatic oil of tobacco to the tongue of a young cat. Instantly violent convulsions took place in all the muscles, and the respirations became very frequent. After eleven minutes she

retched, but did not vomit; in fifteen minutes she appeared to be recovering. The poison was renewed; she was again seized with violent convulsions, and became insensible, breathing at long intervals, and in two minutes from the second application respiration had ceased.

At twenty-one minutes past four I injected into the stomach of a rabbit the eighth of a grain of wourali, dissolved in water. The poison was given to me by my distinguished friend, Mr. Waterton:

H.	M.	
4	24	Respirations much accelerated (175 in the minute).
4	26	Moves the head and body at each respiration.
4	28	Convulsive movements of the whole body.
4	31	The animal ceases to breathe.

Additional observations might be adduced, showing that the usual influence of narcotic poisons is first to accelerate, then to retard, and finally to arrest respiration, but this were needless. The same phenomena are evidenced in all cases of narcotic poisoning. The poisoned blood moves slowly and in increased quantity in the capillaries. The excitability of the incident nerves is first increased, then diminished, and finally exhausted by the poison; and the respirations are in consequence first accelerated, then retarded, and finally arrested.

The depressing effect of tobacco on the muscular and respiratory functions would appear to except that poison from the usual action of the narcotics.

Sir Benjamin Brodie injected four ounces of infusion of tobacco into the rectum of a dog. In four minutes he retched, but did not vomit; he then became faint, and lay motionless on one side; at the end of nine minutes the heart could not be felt; he gasped for breath at long intervals; and in another minute there was no appearance of life. The heart was much distended and motionless.

The following experiment, also performed by Sir Benjamin Brodie, in which tobacco was given to a dog after being beheaded, when compared with the experiment just related, shows the different influence exerted by that poison on the reflex functions when the brain is present and when it is removed.

"In a dog, whose head was removed, I kept up the circulation by means of artificial respiration. I then injected into the stomach and intestines nine ounces of infusion of tobacco. At the time of

the injection, the body of the animal lay perfectly quiet and motionless on the table; the heart acted regularly one hundred times in a minute. Ten minutes afterwards the pulse rose to 140 in a minute; the peristaltic motion of the intestines was much increased, and the voluntary muscles in every part of the body were thrown into repeated and violent spasmodic action. The joints of the extremities were alternately bent and extended; the muscles of the spine, abdomen, and tail alternately relaxed and contracted, so as to turn the whole animal from one side to the other. I made pressure on the abdominal aorta for more than a minute, so as to obstruct the circulation of the blood in the lower extremities; but the muscular contractions were not lessened in consequence. Half-an-hour after the injection of the infusion the artificial respiration was discontinued. The heart continued to act, circulating dark blood; the muscular contractions continued, but gradually diminished in strength and frequency. I tied a ligature round the vessels at the base of the heart, so as to stop the circulation, nevertheless the muscular contractions still continued, though less frequent and forcible than before, and some minutes elapsed before they entirely ceased."

In this experiment, the disposition to contraction in the muscles was very much increased, instead of being diminished, as in those experiments in which the living animal was poisoned in like manner by an infusion of tobacco.

In this experiment, in fact, the influence of the poison on the nervous system was limited to the incident nerves, in their excitor functions, the motor nerves and the medulla spinalis; the brain and the medulla oblongata having been removed. In the former experiments just referred to, the excito-motor phenomena were speedily annihilated; in the experiment just detailed, the excito-motor phenomena were remarkably exalted, the incident nerves being stimulated by the poison circulating everywhere in the capillaries.

The last experiment which I shall add to illustrate the action of the narcotics on the incident nerves, and through them on the respirations, is thus related by the experimenter, Professor Müller:

"The following experiment, which I have performed on frogs, and which on repetition affords the same results, is very instructive. Having divided all the vessels and muscles of the thigh, and

separated them from the bone, leaving the nerve uninjured, I poisoned the frog with nux vomica. The irritability of the sound leg was lost much sooner than that of the leg of which the muscles and vesscls had been divided. After the usual effects of narcotic poisoning on frogs, namely, the state of excitability in which a slight touch generally excites convulsions, had ceased, the muscles of the calf of the injured leg still contracted on my touching any point of the surface of the body; the leg, therefore, which received no blood was sensible to the influence of the spinal cord much longer than the other limb, the nerves and muscles of which had been exposed to the action of the poison circulating in the blood; so that it is going too far to maintain that the poisons act on the central parts of the nervous system only; they act likewise on the nerves through the medium of the circulation."

From the cases and experiments detailed above, I conclude that the narcotic poisons act through the medium of the circulation, not only on the brain and the spinal marrow (myelon) as central organs, but that they also act either through the circulation, or by absorption from without, on the peripheries of the afferent nerves, affecting both their sensory and their excito-motor functions; that they first exalt, then depress, and finally exhaust, first the sensibility and then the excitability of the incident nerves; and that they, through the medium of those nerves,—putting out of sight, for the present, the influence on the brain and spinal marrow,—first increase, then diminish, and finally arrest respiration, unless means be used to resist those effects, and to excite respirations by stimulating the incident nerves, which important practical subject I shall now illustrate and consider.

Treatment of the Effects of the Narcotic Poisons, by stimulating the exhausted excitability of the Incident Nerves, and so exciting respiration.

Under the deep influence of opium the respirations become exceedingly slow. This is well illustrated by the case detailed by Whytt, given at page 217, and by Chossat's experiment on a dog, pagc 186. The respiration, in fact, becomes slower and slower, until it ceases, the circulation being, however, maintained for a time; at length, respiration having ceased, circulation ceases also, and death ensues.

In the treatment of narcotic poisoning, the great objects are to stimulate and maintain respiration and circulation until, through the various channels of exit, and through chemical changes, the poison shall have been eliminated from the system, or rendered harmless by entering into fresh chemical combinations.

Dr. Alison gives, in the twenty-third volume of the *Edinburgh Medical Journal,* the following instructive case of poisoning by laudanum.

The man, aged 35, had swallowed an ounce and a half of laudanum. At first, twenty minutes after taking the poison, his face was flushed, his skin warm, his pulse full, strong, and frequent. Mustard, sulphate of zinc, and ipecacuanha were administered successively, and the fauces were irritated in order to excite vomiting, but in vain. He was now rapidly becoming comatose; face turgid and purplish, breathing stertorous and irregular. He was roused by dashing cold water on his face, applying ammonia to his nostrils, and repeatedly irritating the fauces, and vomiting was at last procured, nearly an hour after taking the poison. Coma, however, supervened. The stomach was emptied through Bryce's tube. He was still unconscious, but made feeble efforts to scratch his legs. He was now stript naked, and cold water was dashed over his head and shoulders. By this he was powerfully excited; he sprang from his seat, and fell forwards, gasping strongly and repeatedly; after this he fell asleep, but was roused from time to time. At six his appearance was altered for the worse. He was quite insensible; his countenance pale and ghastly; lips livid, and jaws fallen; his skin generally cold, although warmth had been applied; his respirations only four or five in the minute, and the inspirations performed with a convulsive start; the pulse small. He had the usual appearance of a person dying comatose; neither dashing cold water on his face, nor pushing a feather dipped in the aqua ammonia up his nostril, produced any immediate effect upon his respiratory muscles.

However, by persevering in the application of ammonia to his nostrils, closing his mouth at the same time so as to secure its complete introduction in the act of inspiration, by pouring a little of the aqua ammonia on his breast, and rubbing it strongly in with warm flannels, continuing the application of hot bottles to his feet and stomach, he was at length roused from the state of coma.

First his breathing became gradually more frequent and regular, and was apparently excited by the vapours of ammonia; then he moved his head from side to side on the irritation of his nostrils, and finally threw his head forward and opened his eyes. The natural temperature of his skin was not completely restored till about ten o'clock, by which time his pulse had become much fuller.

As Dr. Alison remarks, this case illustrates "the peculiar efficacy in a case of poisoning by narcotics, both of the affusion of cold water, and of the stimulation of his nostrils by ammonia. These expedients seem peculiarly useful in this case (just as in the common case of syncope), not merely as general stimulants to the nervous system, but as exciting sensations which have a specific effect on the respiratory muscles. The sensations thus produced, whenever they are strongly felt, uniformly excite the action of inspiration, and thereby, in cases of this kind, contribute to prevent the failure of respiration; and we know, particularly from the experiments of Sir Benjamin Brodie, and from the case recorded by Mr. Whately, that the failure of respiration is the immediate cause of death from the truly narcotic poisons."

In the following case, related by Mr. Walne, in Dr. Bright's Reports, a girl had taken an ounce and a half of laudanum. She was in a state of insensibility. "We raised our patient, and from a pail of cold water kept dashing mugs full upon her head, sometimes in her face. In a very little time she showed signs of sensibility, drew her breath suddenly on receiving the dash of water, moaned dissatisfaction, and sometimes made efforts of resistance. Whenever we discontinued the effusion for a few minutes together she relapsed into a state of insensibility. We continued this treatment, with short occasional intervals, for nearly four hours; in the course of this time we injected a quantity of ammonia into the stomach,—she retched several times, and brought up portions of this and some mucus. Her feet, being cold, were put in hot water. At the end of about four hours the whole skin became cold; she was less roused by the dashing of the water; the heart's action was feeble. We had her placed in a dry bed, and friction, with flannel over the limbs and chest, was used; while hot bricks were applied to her feet. The friction roused the heart and restored warmth, but she continued insensible. In about two hours from the time of discontinuing the cold affusion the jaw fell; the pulse

became hardly perceptible; and her breathing was beginning to be impeded by mucus in the air passages. I determined to try the injection of brandy into the rectum." The sphincter was in a relaxed state. "Four ounces of brandy were thrown into the rectum and quickly and forcibly rejected. It however raised the pulse, and the jaw recovered its natural situation almost immediately after. In about half-an-hour the same quantity was thrown in and retained. She seemed revived by this, slept profoundly, but had a better pulse, and breathed freely. The patient perfectly recovered."

In each of these instructive cases respiration was excited and augmented by stimulating the afferent nerves. That the stimulus acted through those nerves on the spinal marrow and the motor nerves of respiration by an excited reflex action, and not through sensation and the direct action of the brain, is proved in Dr. Alison's case, by the fact that the breathing became more frequent and regular, while he was still unconscious, and in Mr. Walne's case, by the suddenness with which the breath was drawn when she received the dash of cold water.

I have met with the records of eleven cases of poisoning by opium in which the cold dash roused the patient, doubtless with the effect of quickening the respirations. In seven of these cases powerful emetics had been given previously without exciting vomiting; the emetic effect was, however, produced immediately after the stimulus of the cold dash.

When, under the influence of opium, respiration is almost suspended, it may, as we have just seen, be excited by stimulating both the sensory and excito-motor functions of the incident nerves of the surface. Thus, in the cases given above, the lowered respiration was powerfully roused by the sudden dash of cold water on the face and body; by stimulating the nostrils with ammonia; by frictions with ammonia to the surface; by warmth applied to the surface when cold; by the injection of ammonia into the stomach; and by the injection of brandy into the rectum.

In other cases, the depressed respiratory powers have been roused by free exposure to a stream of cold air; by sinapisms; by whipping the surface; by stinging the skin with nettles; and, as a more powerful excitant than all these, by the external application of electricity.

The cases detailed above show that when any stimulant, such as dashing the surface with cold water, has been repeatedly applied for a long time, it at length ceases to act as a stimulus to respiration, and if pushed further, it exhausts the excitability of the incident nerves. They also show that when the respirations can no longer be excited by one stimulus they can be freely excited by another.

The alternate or successive employment of different stimulants is of the utmost importance, if we would continue to excite the respirations when they have become slow and feeble under the influence of narcotic poisons, asphyxia, or any other cause.

Dr. Marshall Hall remarks, that "the most important of all our remedies in congenital asphyxia is the sudden and forcible impression of cold water on the face and general surface. The quantity of the water should not be great, but it should be applied suddenly and with force. The temperature should not be lowered; on the contrary, the dashing of the cold water should be alternated with the warm bath, succeeded by warm flannels. These, too, may be applied briskly and suddenly.

The efficacy of the remedy is in proportion to the degree, the suddenness, the energy of the *alternation*.

Continued cold depresses the energies of life; continued warmth augments them. But it is the sudden impression arising from the brisk alternation of the cold and heat, which proves the most efficacious excitor of the respiratory functions, on which recovery depends."

The principle on which one stimulus successfully replaces another, when that other ceases to have effect, is admirably illustrated by the observations and experiments of Humboldt. He exposed a muscle, shortly after its removal from the living frog, to oxymuriatic acid. The effect was first to stimulate and then to exhaust the muscular contractility. This exhaustion may be removed, he found, by opium, which re-excites and then again exhausts contractility. "This exhaustion may be removed by oxymuriatic acid or oxide of arsenic, while opium also is capable of removing the inexcitability produced by them."

Now, as opium, in these experiments, first increased and then exhausted the contractility of the muscles, so in cases of poisoning, opium first increases and then exhausts the excitability and

sensibility of the incident nervcs, and through their medium first increases and then diminishes the reflex respiratory movements. In like manner, just as oxymuriatie aeid removes the exhaustion indueed in the muscular contractility by opium, and in time renders it again inexeitable, so the sudden and foreible applieation of eold water removes the inexcitability of the incident nerves, occasioned by opium, and exeites through them inereased reflex respiratory movements; on the other hand, the eontinued renewal of eold water exhausts the exeitability of the ineident nerves and the reflex respiratory movements.

The following experiment, performcd by Mr. Nunnelly, shows the effeet of one stimulus in renewing excitability after it had bcen exhausted by another stimulus. A strong frog, whose hind leg had been subjceted to the loeal aetion of chloroform, and amputated above the knee without sensation (which, however, was perfeetly aeute in the other legs), was lying dull, inactive, and flaeeid. It was put into a jar with a few drops of oleum ethereum, when it *instantly* roused up, and jumped most vigorously about for one minute and a half, the fluid aeting as a most decided stimulant. It afterwards became dull, and was kept in until it died.

The following cases illustrate practically the exhausting effect of opium on the reflex funetions; the power to exeite respiration by stimulating the surfaee; and the importanee of alternating or varying the stimulant employed.

A little child, about six months old, was admitted into the Nottingham Hospital, under the influence of half a tea-spoonful of laudanum. Thc ehild was in a state of profound sopor; the pupils werc eontracted; the respirations infrequent. A mustard poultice was applied to the body, and eold water was dashed on the faee, with the cffcet of inereasing the respirations. Eleetro-magnetism was applied to thc head and faec, with the effect of rousing the ehild and exciting deep inspirations, followed by foreible crying expirations. The child was now roused in some degree from the state of sopor, but it still required repeated stimulation. This was done very effectually and easily by every now and then laying the hands of thc ehild, onc on one handle the other on the other handle of the electro-magnetie apparatus. Each time the hands wcre laid on thc handles, the child first took a deep inspiration and then cried.

It was intercsting in this case to notice the extent to whieh the

respirations and sensibility were excited, in proportion as the electro-magnetism was applied, over parts more or less exquisitely supplied with incident nerves. When applied to the body, the surface of which is in comparison feebly endowed with afferent nerves, the electro-magnetism produced but little effect; when applied to the hands, the effect was very marked and instantaneous, the inspirations being deep, and followed by a cry; but when applied to the face, nostrils, and lips, over the extremities of the fifth pair, and especially to the scalp, along the course of the supra-orbital nerve, the respirations and movements were excited to the highest degree, producing the most extraordinary writhings on the part of the child, who was at length roused, and cried loudly and in distress. This case did well.

The other case was that of a young man admitted under the influence of opium, in a state of profound sopor. His breathing was very slow; he could be roused with great difficulty. He was seated in a chair, at each side of which was placed a bucket containing boiling water, his feet were placed in a pail of hot water with mustard, and several blankets were thrown over all, so as to allow the steam to rise around the body, and so to act as a vapour bath. Sinapisms were applied to the body. Electro-magnetism was applied to the face with slight and transient effect. Cold water was then squirted very forcibly over the face and into the ears, from a syringe; this excited the respirations, and caused him to look up for a short time. The electro-magnetism now produced a marked effect, exciting the respiratory functions and causing great annoyance to the poor fellow, who, roused but vacant, said "What, is this eternal torment?" The electro-magnetism was exchanged for ammonia to the nostrils, which likewise roused respiration and consciousness, and that was in turn exchanged for the forcible squirting of cold water over the face, care being afterwards taken to dry the face well and roughly. Each stimulant acted with great effect at first, but each gradually lost power upon repetition, until, by exchanging it for another and that again for another, the excitability to the former stimulus was restored. A catheter was introduced to empty the bladder, and the opportunity was taken to pass electro-magnetic currents in the course of the instrument, with the effect of completely rousing him, at a time when he was excited with great difficulty. After a time consciousness

was restored, but he was in a state of great terror; his surface became at the same time remarkably excitable, a mere touch causing an involuntary start. He was placed in bed, provided with nourishment and stimulants, and was roused from time to time. He recovered, but was the subject of melancholia for some time, and for his own safety he was sent to the asylum for lunatics.

It is of the utmost importance, in treating persons poisoned by opium, not to exhaust either the muscular, the excitor, or the sensory functions. There are several cases on record in which the muscular powers failed irretrievably when the patient was being dragged about between two assistants. By the plans just indicated, the patient being seated in a vapour bath, the poison is eliminated through the perspiration, and by employing a succession or alternation of stimulants, the respiratory and sensory functions are excited but not exhausted. The electro-magnetism ought to be applied to the sentient and excitable surfaces of the face and hands, and not sent through the nervous centres, as thereby we run the risk of exhausting the nervous energies; indeed, if the currents be passed from the occiput to the epigastrium, we excite, not increased inspirations, but continued, forcible, and writhing expirations. If the patient cannot be roused by electro-magnetism to the surface, then it may be applied through the medium of the catheter; and if this should fail, as well as every other means directed to the incident and sensory nerves, then it may be necessary to pass one or two powerful shocks through the nervous centres, so as to rouse the excitability of the patient, exchanging this, however, speedily for the stimulation to the surface.

I object altogether to the copious dashing of cold water; the clothes and the surface are rendered wet by it, evaporation goes on, and the surface becomes chilled. Slapping the face vigorously with a cold wet towel, or the vigorous use of a syringe containing cold water, are equally rousing, and are not so likely to cause depression and chill.

In fevers, during the cold stages, the sensation of cold over the whole surface acts as a stimulus to the afferent nerves, and respiration is much accelerated, being often attended with rigors. The rigors and the accelerated respiration cease with the restoration of warmth. This is illustrated by the following case, in which the rigors followed a fall.

Richard Henson was admitted soon after falling from the top of a house three stories high. He was shortly afterwards attacked by a rigor. His respirations were 42 in the minute. At the end of each inspiration the glottis was closed, and the muscles of the chest, abdomen, and limbs contracted firmly, and with a tremulous, convulsive, alternating action, producing shivering. The vocal chords were separated with a low moaning noise, after which he immediately renewed the act of inspiration. Pulse 66, very feeble indeed. He complained of intense cold, especially in the feet; the body was warm to the touch, but the hands and feet were very cold. The reclining vapour bath, and other means for restoring warmth, were had recourse to; and in one minute the number of respirations fell from 42 in the minute to 14 and 16. In this case the respirations fell in number immediately after the surface was warmed. The inference is, that the coldness of the surface stimulated the afferent nerves so as to excite accelerated breathing.

In the hot, dry stage of fever, the pungent heat of the skin, excited by the roused circulation, acts as a stimulus to respiration. The skin is hot and dry, the pulse quick, and the respirations are accelerated. The application of moist sponging to the skin cools and moistens the surface, brings down the pulse, and lessens the number of respirations.

In some cases of fever, and in some diseases, during the later congestive stages, the respiration becomes slow and laborious. In such cases it is of vital importance that the respiration be quickened. This may be very readily effected in almost all cases, by the successive or alternate means of ammonia to the nostrils, of sinapisms, of stimulating frictions and lotions to the surface, and, if necessary, of electro-magnetism. In these cases, as in cases of narcotic poisoning, the stimulation from electricity or any other excitant must neither be too great nor too long continued; else, while it rouses, it will at the same time exhaust the enfeebled excitability of the incident nerves, and the enfeebled irritability of the muscular system.

In treating cases of the kind just described, bear in mind the following principles of treatment. Arouse the excitability and sensibility of the afferent nerves to such a degree as to render the imperfect respirations valid, and to awaken consciousness; use a stimulus just strong enough to achieve those purposes; do not push the stimulus so far as to excite the nervous and muscular energies

to excess, lest by exhausting those energies you shorten instead of lengthening life. When one stimulus begins to lose its effect, replace it by another stimulus of a different kind.

There is a large class of persons in whom the whole surface possesses extraordinary scnsibility; I allude to the hysterical. In these a mere touch will often excite exquisite pain. The excitor as well as the sensory functions of the afferent nerves are affected in these persons. Their respirations are habitually quick and short; the excitability of the surface to impression is sometimes exalted to an extraordinary degree, and then the hysterical fit or paroxysm comes on, in which the expiratory and the inspiratory muscles are violently, variously, and irregularly excited. Sometimes the inspirations are impeded or interrupted by the approximation of the vocal chords, a remarkable variety in respiration that I shall consider by and bye. Sometimes during the paroxysm the respirations are excessively quick and short; I have observed them 112 in a minute. There is frequently a want of simultaneous co-operation in the various acts of respiration; the vocal chords are often energetically approximated instead of being drawn asunder during inspiration; and in one case, a female in whom the respirations were habitually much accelerated, the nostrils, instead of being dilated during inspiration, were dilated during expiration.

For the description of the respiratory phenomena during an hysterical fit, I refer to the cases given at a subsequent part of this paper. The effect of exposing the surface to cold air, and of dashing cold water on the face and body, when the patient is unconscious and in a fit, in exciting inspiratory widening of the glottis and normal full inspirations, gradually rendering the patient conscious, and putting an end to the paroxysm, is well illustrated in the cases there given. That the deep inspirations are induced through the medium, not of the sensory, but of the excitor functions of the afferent nerves, is proved in the case of Marriott, since, although she was unconscious, when cold water was dashed on the surface an immediate deep inspiration was excited, during which she corrugated the eyelids, opened the mouth, drew back the head at first, and then took several deep inspirations; she soon, however, relapsed, again taking short, quick, noisy inspirations, they being impeded by the stridulous approximation of the vocal chords.

She still remained unconscious, and it was not until the repetition of the dashing for eight or ten times that she became sensible; she being at length roused by the repeated renewal of the stimulus and the augmented circulation and respiration.

The relation of the sensory and excitor functions to each other is well exhibited in the case of hysteria just considered. In hysterical persons the surface is exquisitely sensible, and the excitor functions of the afferent nerves are very easily stimulated. We have seen above, that at whatever part of the surface sensation was exquisite, there the excitor functions are readily excitable. We now see that when sensation is unusually exquisite, the exalted sensory function is accompanied by a relatively exalted excitor function of the afferent nerves. When, however, during the paroxysm, the sensory functions are suspended, the excitor functions are still exalted and abnormal, but are readily stimulated so as to excite normal but exaggerated reflex respiratory movements. When sensation returns, then the excitor functions are somewhat controlled.

The Effects of External Warmth and External Cold on Respiration.

This subject is so important, and so extensive in its bearings, that although it forms a part only of that subject which I am now specially considering,—the effect, namely, of external stimulants on respiration, yet I shall devote a separate sub-section to its consideration.

The great purposes of respiration are the same, and the laws regulating the causes of respiration, though they differ in detail, are alike in principle in all animals. I purpose to consider here the effects of external temperature on respiration in those classes of animals which possess a circulation.

The temperature of the great majority of beings is very little above that of the surrounding medium. Consequently, when the external temperature sinks or rises, the temperature of the animal sinks or rises in proportion. I allude here to the whole of the cold-blooded animals. That great purpose of respiration, the decomposition and removal of the used and waste materials of the organism, is not required when the temperature of the animal is so low as to be at freezing point, or a few degrees only above that point. Since then all chemical action is suspended, none of the

component parts of the organism are cast off, and no new parts are required to supply the place of effete materials; food is consequently not necessary, indeed it could not be digested, all chemical processes being suspended under the influence of a low temperature. Indeed, at the temperature referred to the decomposition of the dead body is at a stand-still; and as that of the living body is then suspended respiration, being unnecessary, is suspended likewise.

When the temperature is at or only a little above the freezing point, almost all those beings which cease to respire, cease to move or to become capable of motion; they become lethargic and unconscious; there is no occasion for energy or consciousness on their part, and nature, with her customary thrift, does not endow the creature with consciousness unless its possession be necessary.

Those animals of the higher classes which hybernate do not require the immediate possession of consciousness when roused from torpor, and they recover energy and consciousness slowly. Among hybernating animals, those which require food most quickly regain their consciousness most quickly.

Those higher animals which do not hybernate have the power of evolving sufficient animal heat to maintain their bodies at a certain standard temperature; this power is necessary to the ready possession of full consciousness, and the constant power of quickly regaining consciousness when they awake is necessary in order that they may either attack their prey and defend themselves, or escape if attacked.

Many of those animals which live in burrows or holes, and do not require for self-preservation the immediate possession of consciousness and energy, do not produce during sleep and when exposed to cold the full amount of animal heat requisite for immediate energy and consciousness.

In the warm-blooded non-hybernating animals one of the great purposes of respiration is the maintenance of animal heat at a certain standard; consequently, within certain limits, when the external temperature falls, the evolution of animal heat increases, and when the external temperature rises, the evolution of animal heat diminishes. This is exactly opposite to the effect of external temperature on the evolution of animal heat in those animals which have no proper standard of animal heat, for in them, under

ordinary circumstances, the power to evolve heat increases with the rise and diminishes with the fall of the external temperature.

For hybernating animals there is a certain minimum temperature, below which they cannot fall without the loss of life. If they, when they are torpid, fall in temperature to the extent referred to, they are roused from their torpor, and maintain for a time an independent temperature.

The maintenance of animal heat above the atmosphere is required by many of the cold-blooded animals, especially when they require the exercise of unusual energy.

Effects of External Temperature on the Respiration of Snails.

Spallanzani observed the effect of temperature on the respiration of snails. He found that six viviparous snails, the respiration of which is wholly cutaneous, consumed no oxygen during 72 hours, when the temperature was as low as from 37° to 39°. On the 11th of March, when the temperature was 51°.6, six viviparous snails consumed in 80 hours .03 of a measure adopted by the experimenter, while on the 2nd of August, six of those snails consumed in 80 hours .05.

Spallanzani observed, that if the common snail be removed from a heated to a cold room, the respiratory dilatation and collapse of its air-sac become less frequent, the pulsations of the heart become slower, and the motion of the fluids in the blood-vessels diminishes. If the temperature be reduced to the freezing point, the movements of the air-sac, the pulsations of the heart, and the circulation in the blood-vessels, cease. If the creature be kept at this temperature for days, neither circulation nor respiration is to be perceived. If it be replaced in a milder temperature, the air-sac first moves, and then the pulsations of the heart and the circulation in the blood-vessels are renewed.

John Hunter found that slugs had a temperature of $55\frac{1}{4}°$, when that of the air was 54°; he also found that when a snail was placed in air below freezing point, the temperature of the snail fell to 31°, and that then the creature froze and perished.

Spallanzani found that the snail absorbed no oxygen in December, when the external temperature was 39°, and in February, when it was 44°. On the 11th of April, the operculum, which had

hitherto been fixed, was in a softening state, the circulation was quickened and the amount of oxygen consumed in a given period was 9 degrees of the measure employed. At a later and warmer period of the year, when the air-sac opened and closed freely and frequently, the six snails consumed 20 degrees of oxygen during the same period.

These observations show, that in the snail the increase of the external warmth causes progressive increase in the respiratory consumption of oxygen, and excites anew the respiratory movements which had ceased, quickening or renewing at the same time the circulatory movements which had become imperceptible to the eye.

The immediate application of warmth to the surface was the exciting cause of the renewed and increased respiration and circulation.

Effects of External Temperature on the Respiration of Insects.

In the beginning of January, Mr. Newport found some of his bees torpid and motionless in a room at a temperature of about 40°; he removed them into another room, the temperature of which was 60°. They soon gave signs of revivescence. At first there were slight twitchings of the tarsi, and feeble irregular contractions of the abdominal segments, which increased in frequency.

In 2 minutes	the respiratory contractions of the abdomen became more regular	58 in the minute.
In 4 minutes,	number of respirations ...	63 in the minute.
6 minutes	,, ,, ,, ,, ...	72 in the minute.
11 minutes	,, ,, ,, ,, ...	80 in the minute.
15 minutes,	animal began to move its limbs ,, ...	77 in the minute.
20 minutes	... ... ,, ...	87 in the minute.
33 minutes,	had regained power of locomotion ,, ...	102 in the minute.
When perfectly recovered and in a state of activity	,, ...	160 in the minute.

The usual number of normal respirations is 40 in the minute.

Mr. Newport found that the pupæ of the Sphinx Ligustri produced a greater amount of carbonic acid in a warm than a cold atmosphere. He placed two of these pupæ in a bottle in the open air, the temperature ranging between 35° and 58°, and another in a room, at a temperature varying from 45° to 60°, and he found that the pupa in the room produced 0.40 of a cubic inch of carbonic acid in 180 hours, while each of those exposed to the colder temperature, evolved only 0.19 of a cubic inch in 156 hours.

During the progress of the year, from the winter to the summer months, as the external temperature increases, the heat of the bee increases likewise; but this increase of temperature on the part of external medium and the bee is not at equal rates, far from it, for up to the time of swarming the increase in temperature of the insect is far greater than that of the atmosphere. Thus—

During February, 1836,		mean temp. of atmosphere ...	40°.35,	of hive	50°.10,	excess of temp. of hive over that of atmos.		9°.75
March,	,,	,,	46°.93,	,,	58°.59,	,,		11°.66
April,	,,	,,	49°.93,	,,	73°.07,	,,		23°.14
May,	,,	Time of swarming,	60°.17,	,,	87°.08,	,,		26°.91
After swarming.								
June,	,,	temp. of atmos.,	63°.67,	,,	89°.11,	,,		25°.44
July,	,,	,,	63°.68,	,,	79°.77,	,,		16°.09
August,	,,	,,	67°.64,	,,	77°.79,	,,		10°.15
Sept.,	,,	,,	60°.04,	,,	66°.5,	,,		6°.46

During the first four months the progressive increase in external temperature leads to a progressive increase in the independent evolution of heat, owing to the progressively augmented respiration. After the great purposes of swarming have been served, the occasion for an exalted temperature having gone by, the respiratory evolution of heat gradually diminishes.

The following communication, with which I have been favoured by Mr. W. F. Barlow, illustrates with remarkable precision the effect of heat and cold on the respiration of insects:—

"Westminster Hospital, Dec. 21, 1849.

"My Dear Sir,—I send you a few short notes of some of the unpublished experiments which I mentioned to you.

"I have observed that the respiratory movements of the dragon-fly become by immersion in cold water slower and slower, and at length very gradually cease; but on re-exposing the insect to air, it soon begins to breathe visibly again, and the respiratory motions, becoming stronger and stronger, are in the end quite restored.

"I have found that by exposing the insect to hot air or water, I could accelerate its respiratory movements at pleasure. I put one, for instance, (the respiratory movements being about 75 in the minute), into water of the temperature of 100°, and the contractions rose to the rate of 110. On removing the insect, and exposing it to cold air, they soon fell to 50. I have made several other experiments, which show that, within certain limits, elevation of temperature leads to a corresponding quickening of the respiratory movements.

"I have noted that water at the temperature of 130° very rapidly extinguished all motion.

"On the other hand, the respiratory motions may be diminished by applying various degrees of cold. By immersing the insect in water of different temperatures, I have found that the lower the temperature the slower did the respiratory movements become. I made some experiments with a freezing mixture, and found it had the effect of almost instantly arresting the respiratory contractions.

"But an observation of nature, independently of experiment, teaches us the same knowledge. The dragon-fly, when caught on a cold morning at the end of September or the beginning of October, is performing no visible respiratory contractions, or only such as are extremely slow, few, and feeble; but the same insects captured at noon, when swiftly flying in the sunshine in quest of prey, will be seen to respire with great quickness and full vigour.

"I am, my dear Sir,

"Yours very faithfully,

"W. F. BARLOW.

"Dr. Sibson."

In a subsequent note Mr. Barlow states, "I held a dragon-fly, whose cerebral analogue I had destroyed, over water of the temperature of 185°, with the effect of greatly accelerating the respiratory movements.

"I have found also that the respiratory movements of the insect are readily hurried by placing it on a hot surface. I used on one or more occasions a stone bottle, filled with water of a high temperature.

"In whatever way heat is applied, the movements are quickened.

"I have concluded that the heat acts on the periphery of the nerves, and excites the contractions reflexly."

The interesting observations of Mr. Barlow, which he will, I trust, shortly publish in full, taken in conjunction with those of Mr. Newport, show how absolutely the movements of respiration are excited, controlled, depressed, and arrested by external temperature.

At the freezing point respiration is arrested; with the increasing external stimulus of increasing heat the respiratory movements are, up to a certain point, progressively accelerated; at 130° those movements are extinguished. That the stimulus exciting the reflex respiratory movements is applied to the cutaneous nerves, and not to the tracheal nerves, is proved, inasmuch as the respirations,

when arrested, are at first excited to renewal by the application of warmth to the surface; indeed in those important experiments in which the insects were immersed in water of various temperatures, the stimulus was applied immediately and only to the surface, the movements of respiration being accelerated in proportion to the increase of temperature, notwithstanding that the submersion prevented the inspiratory admission of air into the trachea. The experiment in which the external application of heat increased the respiration, although the cerebral analogue was removed, proves that the augmented movements are not due to volition.

The observations of Mr. Newport show that there is a certain medium temperature, ranging somewhere between 40° and 50°, at which the bee may when at rest retain the same temperature as the external medium. But if the temperature fall below this range, there will be an independent evolution of heat by that interesting insect, and its temperature will be above that of the atmosphere. Thus—

Date.	Temperature of atmosphere.	Temperature of hive.	Difference between temperature of air and hive.
On the 12th of Nov., 1835, 4 P.M. ...	41°.2 ...	41°.2 ...	°0
13th ,, 7½ A.M. ...	36°. ...	43°.7 ...	7°.7
16th ,, 4½ P.M. ...	37°.6 ...	46°.7 ...	9°.1
17th ,, 7½ A.M. ...	39°.5 ...	45°. ...	5°.5
,, ,, 9½ ,, ...	43°.6 ...	45°.5 ...	1°.9
,, ,, 10½ ,, ...	45°.2 ...	46°.8 ...	1°.6
,, ,, 11½ ,, ...	47°.4 ...	47°.4 ...	°0

During all these observations the insects were quiet.

Mr. Newport remarks, that "the hive-bee certainly does not become *torpid*, but if entirely undisturbed it passes into that condition in which its temperature of body and quantity of respirations are very greatly diminished,—a state of deep sleep in the combs, but a sleep which, so far from being continued at a very low atmospheric temperature, then becomes broken, and is only continued at a moderate temperature."

It would appear, then, that respiration may be, to a certain extent, excited in the hive-bee by a greatly lowered temperature, with the view of sustaining its temperature, and so enabling it quickly to renew consciousness and increase its temperature to a very great extent, as we have already seen at page 185.

Thus the hive-bee appears to be endowed with a faculty of which the dragon-fly is destitute, the faculty of evolving heat by respiration at exceedingly low temperatures.

Effects of External Temperature on the Respiration of Fishes.

Spallanzani found that a fish lost its activity in half-an-hour when placed in water at 32°, but it still moved when touched. The opercular movements were seven in the minute.

He almost froze a fish in air, at a temperature of 25°, and he then placed it in water at 37°.4. It showed no signs of life for an hour; it then began to move its fins, and soon after it commenced to breathe. Next day it was dead. A fish, when placed in air at 26°, opened the opercula eight times in a minute; after the lapse of a quarter-of-an-hour it only breathed when touched. When taken in the hand it agitated itself. It swam freely in water at 31°, and in the course of the night it absorbed oxygen and produced carbonic acid in small quantities.

John Hunter put two carp into a vessel of water, and placed it in a freezing mixture; they resisted the effect of the cold a long time, moving about violently. At length, however, they were frozen, and when thawed they did not recover.

In an eel, the heat in the stomach, at first 37°, sank after it had been some time in the cold mixture to 31°. The animal at that time appeared dead, but was found to be alive next day.

Dr. Edwards found that if a bleak be placed in five ounces and a half of exposed aerated water, at a temperature of 68°, it dies in a few hours, but when the temperature is lowered to 50° or 53°, and is kept at that degree, the animal lives until its secretions are so abundant as to corrupt the water.

In order to observe the effects of temperature on the respiration of fishes, I noticed the opercular movements of a gold fish, under the following circumstances.

On the 30th of December, at 35 minutes past 10, snow being on the ground, the opercular movements of a gold fish in water at a temperature of 51°, were 52 in a minute, the fish being perfectly still, and its fins at rest. The water had been in the room all night.

	In water at a temp. of		Opercular Movements.
10h. 35m.	51°	The opercular movements of the gold fish were	52 in the minute.
10h. 55m.	38° to 34°	snow was put into the water, the temperature of which fell progressively to 38°, 37°, 36°, and 34°. No opercular movements were perceptible; it was quiet, but moved when disturbed, making irregular body, fin, and tail strokes, about 30 in half a minute	0
11h. 5m.	42°	Warm water was added, so as to raise the temperature to 42°. The fish swam about, and then became still	49 in the minute.
		The temperature was then raised progressively by successive additions of hot water.	
11h. 10m.	46°	The fish lay still at the bottom of the dish	24 + 22 in 30″ = 46 in the minute.
11h. 20m.	50°	Body nearly still; some fin movements	66 in the minute.
11h. 25m.	55°	Opercular movements irregular in extent and rhythm; oral, opercular, and fin movements simultaneous	37 + 39 in 30″ = 76 in the minute.
11h. 29m.	60°	Fish stationary; sudden body and tail vibrations; at length it moved away	47 in 30″ = 94 in the minute.
11h. 34m.	65°	Oral and fin movements simultaneous	50 in 30″ = 100 in the minute.
11h. 37m.	64°	After being chased round the dish	23 in 15″ = 92 in the minute.
11h. 38m.		Fish still	30 in 15″ = 120 in the minute.
11h. 45m.	70°	Fish came to the top; very slight movement of pectoral fins with each opercular movement	62 + 53 in 30″ = 115 in the minute.
11h. 48m.	68½°	Fish undisturbed	30 in 15′ = 120 in the minute.
		After being disturbed	60 in 30″ = 120 in the minute.
11h. 55m.	74½°	The animal in a state of agitation, moving quickly about	58 in 30″ = 116 in the minute.
11h. 56m.	74°	Fish at top; little movement, except of anterior fins	68 in 30″ = 136 in the minute.
11h. 58m.	72½°	After being chased, the fish then moving	69 in 30″ = 138 in the minute.
12h. 1m.	79°	Fish floating at the top; fins and opercula move simultaneously	78 in 30″ = 156 in the minute.
12h. 5m.	84°	Fish moves with a convulsive, wriggling, forward motion. Number of respirations difficult to observe	70 in 30″ = 118 in the minute.
12h. 9m.	88½°	Lying on one side at the top, moving fin occasionally, opening mouth only once in 15 seconds; opercula move slightly	27 in 15″ = 108 in the minute.
12h. 10m.		Opercula at rest	0
12h. 11m.		After a short time very slight oral movements, 5 in 15″	
12h. 12m.		Opercular movement very slight	10 in 15″ = 40 in the minute.
12h. 15m	84°	Opercular movements slight, but manifest	24 in 20″ = 72 in the minute.
12h. 17m.	83°	Opercular movements more extensive, still irregular	17 in 30″ = 34 in the minute.
12h. 22m.	70°	Cold water added. Fish lay floating on one side at the top, almost motionless; slight fin movements; one or two opercular movements	1 or 2 in the minute.
12h. 25m.	60°	Occasional fin and body movements; opercular movement very slight indeed	38 in 30″ = 76 in the minute.
12h. 28m.	55°	Fish motionless, and lying at bottom on the belly; 25 body and head movements in 15″	100 in the minute.
12h. 41m.	55°	Fish still at the bottom; opercular movements more extensive	21 in 30″ = 42 in the minute.

The fish recovered perfectly.

It is to be observed that boiled water was added to heat the fluid containing the fish, consequently the experiment is complicated, the fish undergoing the conjoint influence of increased temperature and diminished oxygen.

During a previous experiment, the steps of which were exactly the same with that detailed, when the temperature was becoming very high, the motion of the fish became convulsive, startling, and sudden, the opercular movements being very great; afterwards it lay almost still on one side, floating at the top of the water. At length the temperature was raised to the highest pitch (about 90°?) The fish leaped violently up, so as to have its head out of the water; repeated this, and then lay motionless and side uppermost at the top; the motionless operculum was quite out of the water. At first there were a few faint opercular and occasional convulsive sidelong movements; at length it lay as if dead.

The temperature was lowered by pouring in cold water, and the fish recovered as in the experiment described above.

The experiments and observations given above, show that the respiratory movements of the fish progressively decrease with the decrease of temperature, until at 34° they are not perceptible, and that with the gradual rise of temperature they progressively increase in number and extent, being excited by the external stimulus; at length, the greatly augmented temperature of 90° exhausts the excitability of the animal; after convulsive movements the respiration comes to a stand-still, being, however, renewed again with the lowering of the temperature.

Although the opercular movements are not perceptible at the freezing point, they probably take place, while cutaneous respiration evidently goes on, for those fish which are then active still evolve a certain amount of heat. The eel does not seem to possess this faculty, but with the lowering of the temperature appears to become inactive, and to lose the power to evolve heat. Dr. Davy found the temperature of the eel the same with that of the surrounding water.

The difference in the respiratory power and activity at lower temperatures of the carp and the eel, is evidently due to the necessity which the former fish then has for the quick use of its

locomotive and sensory faculties, in order that it may eludc capture. The eel, being concealed from observation, does not then require the locomotive, sensitive, and respiratory faculties of the more active fishes.

Effects of Temperature on the Respiration of Frogs.

Dr. Edwards put frogs into a pint of Seine water at a temperature varying from 32° to 108°, with the following results:—

Eight frogs, each in 0.35 pint of Seine water, at a temperature of 32°. They died in from							6h. 7m. to 8h. 18m.
Two	,,	50°	,,	,,	,,	...	5h. 50m. to 6h. 15m.
Four	,,	72°	,,	,,	,,	...	35m. to 1h. 10m.
Three	,,	90°	,,	,,	,,	...	12m. to 32m.
Ten	,,	108°	,,	,,	,,	...	a few seconds to 2m.

Here the progressive increase of temperature caused a progressive increase in the rapidity of death; in other words, the amount of air necessary for the respiration of frogs increased with the increase of temperature.

A frog can live in aerated water, without breathing air, at a temperature below 50°, but if the temperature be above 50° they die after a period varying inversely with the increase of temperature. If they are at liberty, they rise to the surface, and breathe the air, the necessity for breathing the air increasing with the increase of temperature. In winter frogs can live in aerated water by means of cutaneous respiration alone; the lungs may then even be cut out, and yet life will continue. In summer both pulmonary and cutaneous respirations are necessary.

Tadpoles change during the warm season. If the influence of the warmth be not sufficient, their transformation is deferred until the following summer; and if they are limited to cutaneous respiration, not being suffered to breathe the air, their transformation is indefinitely delayed.

In winter, the frog is in an inactive state, and then cutaneous respiration is sufficient for its existence; but in summer its activity is great, and then both cutaneous and pulmonary respiration are requisite.

If the frog be confined, at a moderately warm temperature, to cutaneous respiration in running water, although it lives, its condition is inactive and inexcitable.

A large frog was placed in a small apartment, having a temperature varying from 108°.5 to 112°. The respirations were progressively accelerated.

A progressive decrease of temperature progressively diminishes the respirations of frogs, until, below the freezing point, they are arrested; while a progressive increase in temperature gradually accelerates the respiration of frogs, until, beyond a certain temperature, they cannot maintain life.

As we have seen above, a frog placed in a highly heated atmosphere, keeps down its temperature within the limit of 100° by means of cutaneous and pulmonary evaporation.

Berthold found that frogs have usually the same temperature with the surrounding water, but that they have, owing to evaporation, a lower temperature than the surrounding air. Tiedemann observed, that at night, when the water was frozen, a frog had a temperature of 33°, the water around it being unfrozen.

Sir Charles Hastings observed the effect of the extremes of heat and cold on the circulation in the web of the frog's foot. He found that when he applied warm water at 115° to the frog's foot, the blood immediately quickened, the vessels being in some degree contracted. After dipping the foot five times in warm water, the vessels were much dilated, and the blood formed a red mass, moving slowly in the capillaries. After 25 minutes, he applied ice; in a quarter-of-an-hour the vessels again contracted, the globules re-appeared, and the natural motions were restored.

Sir Charles Hastings, on another occasion, applied ice to the web of a frog's foot. In five minutes the motion of the blood increased, the vessels being contracted. The ice being still applied, the vessels at length dilated, and the blood circulated more slowly.

The immediate effect of external temperature is evidently upon the circulation in the superficial capillaries. The altered circulation, as well as the external impression, acts on the incident nerves so as to quicken, excite, or depress respiration by reflex action.

Effects of External Temperature on the Respiration of Warm-blooded Animals.

External temperature acts, as we have just seen, on the respiration of the cold-blooded classes with a very simple and intelligible uniformity. In these classes increased warmth, up to a certain

point, uniformly excites and increases respiration, while increased cold depresses and finally arrests respiration. Their active life is confined to the summer; in winter they are either inactive, torpid, or dead. By a remarkable arrangement in the warm-blooded animals, extremes both of warmth and cold accelerate respiration. These animals possess a certain standard of animal heat. In cold weather the augmented respiration causes the increased evolution of animal heat, so as to maintain that standard above the external temperature. In very hot weather, the temperature being above 100°, the accelerated respiration causes increased evaporation, and so, by acting as a cooling process, maintains that standard below the external temperature. These classes are consequently endowed with energies of equal activity in winter and summer, and often possess even greater energies in cold than in warm climates.

While in all animals the decomposition and elimination of the waste materials of the body constitute the great function of respiration, the evolution of animal heat, in such proportion as to augment the heat of the being up to a certain standard, is an additional essential purpose of respiration in the warm-blooded animals. The more active the decomposition of the materials of the organism, the greater is the evolution of animal heat. The processes of respiration are more energetic in the higher warm-blooded classes in winter than in summer.

We have already seen how completely this condition is reversed in the cold-blooded animals.

Now, although these two classes, taking them, one in its higher the other in its lower phases, differ from each other so widely, in the season at which they each generate the greatest amount of heat, and in the power of generating heat, yet the higher of the cold-blooded and the lower of the warm-blooded animals approach each other closely in their power to generate heat in proportion to the external cold and warmth. For instance, while the bee can maintain a temperature, both in summer and winter, much above the surrounding medium, thus possessing the qualities of a warm-blooded animal, the hybernating mammalia become torpid under the influence of cold, actually appear to cease to respire, and possess a temperature identical with the surrounding atmosphere. The analogy goes even still farther, for while both the bee and the hybernating mammalia, at a certain low temperature, have

apparently a complete suspension of respiration, and a temperature identical with the atmosphere, they each have their respiration roused by a temperature colder than that at which they hybernate, so that, by an independent and conservative evolution of heat, their temperature becomes actually and considerably elevated; they each also possess the remarkable faculty, if roused by irritation, of evolving a degree of heat which will raise them up to the standard of the highest summer temperature. Indeed, as we have seen already, the bee possesses this faculty in much greater perfection, and can, in fact, exercise it with greater rapidity than the hybernating animal. Guided by these analogies, I will first consider the effect of external respiration on the hybernating animals.

Effects of External Temperature on the Respiration of Hybernating Mammalia.

M. Saissy's observations, given in a table at page 191, show that the hybernating animals possess in summer about the same temperature as the permanently warm-blooded animals.

DORMOUSE.

	Temp. of air.	Temp. in Axilla.	Resp. in min.	Oxy. con. in hour, cubic in., Fr.	Pulsations in min.
Aug. 6th to 12th, lively	64°.4 to 68°	97°.5	45	34.6	105
Nov. 8th to 11th, conscious	44°.6	69°.8	30	20.53	60
Commencing hybernation	...	...	9 to 10	...	20 to 25
Feb. 2d, hybernating	32°	38°.5	...	0	9 to 10

We have seen, that with the decline of temperature there is a steady decline in the number of respirations, the amount of oxygen consumed, the temperature of the body, and the pulsations of the heart, until at length respiration and the consumption of oxygen apparently cease when the temperature falls as low as 38°.5, or rather, as Dr. Marshall Hall has shown, as low as the surrounding medium; varying, indeed, with the variations in temperature of that medium.

If the external temperature be much and quickly lowered, respirations are again excited and gradually accelerated, the animal being still unconscious; the animal heat gradually rises, and the creature becomes gradually more and more conscious, until at length it becomes lively.

On the 25th of January, 1807, at ten o'clock a.m., M. Saissy placed a hedgehog and dormouse, their bodies having a temperature of 39°.2, at a window open to the north, the external temperature being 24°.8. Their respiration gave a few feeble signs of existence.

A few minutes before eleven the dormouse awoke, was lively, and ran about its cage. At eleven o'clock its temperature had risen to 77° (38° in one hour), and at twelve o'clock to 96°.8 (58° in two hours.)

The hedgehog awoke at half-past twelve, when its temperature had risen only to 53°.6 (14° in two hours and a half); at three o'clock p.m. its temperature was 82°.4 (43° in five hours.) The animal remained another hour exposed to the intense cold, when its temperature had fallen nearly 4°.

In these instances the increased cold served as a stimulus, exciting acts of respiration through the impression made on the incident nerves.

These instructive experiments show that the warm-blooded animals, even when of the lower or hybernating class, can elevate their temperature by means of respiration, so as to be, in the instance of the dormouse, 72° above the surrounding atmosphere.

The observations of Dr. Marshall Hall show, that if the intense cold which arouses the hybernating animal continue, the creature will again lose the temperature it has acquired, become torpid, and at length die from exposure to cold. Indeed, hybernation is incompatible with very low temperatures.

Some observations made by M. Regnault on the respiration of the marmot during its hybernating state, and just when being aroused from that state, confirm and illustrate the observations of M. Saissy.

Early in March, 1848, when the temperature was 46°.4, M. Regnault placed in his apparatus for accurately observing the chemical changes induced by respiration a marmot, in a state of hybernation; it exhibited no movement, and its temperature was 53°.6. (It may be remarked that M. Saissy found the temperature of a marmot, in a profound state of hybernation, to be 41°.) He kept the animal under observation for 117 hours, and found that it consumed a very small proportion of oxygen,—only 0.004 per cent. of the weight of its body in the hour.

On the 27th of March, the external temperature being 50°, the marmot was re-introduced into the apparatus, its temperature in

the anus was 52° ; its state of hybernation was less deep, it opened its eyes when touched, and respired occasionally. On the 30th of March, about 45 minutes before the end of the experiment, the animal became agitated, its movements were more rapid, and the consumption of oxygen was much more considerable ; of the whole quantity consumed during the 77 hours the experiment lasted, about one-third was consumed during the last short period, when the creature was lively. At the conclusion of the experiment the temperature had risen from 52° to 71.°8, and five hours later, to 84.°2. The creature was very lively and vicious when it was taken out of the apparatus.

At a later period, when the temperature was 59°, the animal being lively, it was re-introduced into the apparatus just after eating. It remained there for 41 hours 10 minutes, and it consumed, during that time, .0774 per cent. of the weight of its body of oxygen per hour, or nearly 20 times as much as it consumed when in a state of hybernation.

On the 17th of June, the temperature being 68°, it was again observed for 68 hours. During the first day it was lively, and ate freely; on the second day it fell into a torpid state, when the consumption of oxygen was notably lessened.

Dr. Edwards remarks, that there are some adult species of the class mammalia which, though not passing the winter in a torpid state, closely resemble hybernating animals in their feeble power of producing heat. Mice are of this number. To retain their warmth they make nests, not for their young only, but for themselves. Most of those animals which burrow or inhabit caverns and crevices in rocks or holes, in walls or trees, are of this class. Their dwelling-places serve as a protection from the cold, which many of those animals cannot bear with impunity.

Effects of External Temperature on the Young of certain Mammalia and Birds.

Dr. Edwards has shown that the new-born young of certain mammalia and birds are incapable of supporting animal heat when exposed at ordinary temperatures.

If at a temperature between 50° and 68°, a new-born puppy be removed from its mother, although its respiration be much

accelerated, yet its temperature falls considerably, and continues falling until, in the course of three or four hours, it stops a very few degrees above that of the surrounding air.

On the 12th of February, 1819, a kitten, newly littered, removed from its mother and exposed to the air, at the temperature of 51°, being cooled down in nine hours to 64°.4, became stiff, and almost incapable of executing the slightest movements.

Two kittens, one day old, having a temperature of 98°.6, were exposed to the air of a room at 50°. In two hours and twenty-five minutes the temperature of one was reduced to 62°.6, of the other to 64°.4. They were stiff and almost motionless.

In January four puppies, a day old, of the temperature of 95° to 97°, were exposed to the air of a room at 52°. In thirteen hours their temperature had fallen to 55°.4 and 57°. They were then so enfeebled as to be almost motionless.

Dr. Edwards exposed young and adult magpies to a temperature of 39°; while a young bird lost 29° in seventy minutes, the adult only lost 5°.

It appears that young sparrows will live nine times as long in the same quantity of air as adult sparrows. The inference is that they consume a smaller proportion of oxygen.

Respiration is accelerated in the young by exposure to cold, owing to the stimulation of the incident nerves of the surface, respiration being excited by a reflex action.

New-born puppies can live two or three days at a temperature of 64°.4 to 68°; but the air must not be too cold, or they will be deprived of sense and motion, and at length die. When they appeared on the point of expiring Dr. Edwards easily restored animation by placing them before a fire.

Effects of external temperature on the Respiration of higher Adult Warm-blooded Animals.

Effects of moderate Cold.

We have just seen the effect of exposure to moderately cold air, in lowering the temperature and respiration of hybernating animals, and in lowering the temperature while it accelerates the breathing of certain young animals.

Dr. Edwards has made some interesting and exact observations

on the effect of exposure to the air of young birds when nearly or quite able to sustain their own heat at a moderate temperature.

A YOUNG BIRD.

Its temperature in the nest.	Resp. per min. in the nest.	Was exposed to air of room at	The respirations were then	It lost in a quarter of an hour.
104°	97	64°	120	5°.4

Its respirations were afterwards fuller and slower. It then retained the lower temperature.

ANOTHER YOUNG BIRD.

100°4	84	64°	108	1°.3

At the end of an hour it had recovered its original temperature, 100°.4. Respirations then 108.

In a third, the respiration was accelerated, and its temperature, instead of falling, rose one degree.

In these instances, the exposure to a moderate cold increased the respirations, the first bird thereby sustained its heat, to within a few degrees of the heat acquired from its mother; while in the third the accelerated respiration, stimulated by the exposure, actually raised the already high temperature of the creature.

In adult age, the rapidity of the respiratory movements is less subject to the influence of external temperature; but in all the experiments made by Dr. Edwards on the refrigeration of the higher adult warm-blooded animals, he remarked an acceleration of the respiratory movements, until, the powers being exhausted, these movements, like all the others, languish and fail.

Vierordt observed the condition of his own respirations for fifteen months, and he found that in cold weather the respiration and pulse are accelerated, that the volume of each expiration is augmented, and that the proportion of carbonic acid contained in each expiration, as well as the total amount of carbonic acid evolved, is increased. He gives the results in the following table, which I quote from Dr. Reid's article on respiration. The observations were taken during temperatures varying from 37°.4 to 75°.2:—

	Average of the observations Taken at the lower temperature, 47°.24.	Taken at the higher temperature, 66°.92.	Difference between the higher and lower temp.
Pulse, per minute	72.93	71.29	1.64
Respirations, per minute	12.16	11.57	0.59
Volume of an expiration, cubic inches	33.44	31.76	1.68
Expired air, per minute, cubic in....	406.99	366.97	40.02
Expired carb. acid, per min., cub. in.	18.25	15.72	2.53
Carbonic acid in 100 parts of the expired air, cubic inches	4.48	4.28	0.20

Lettellier found that the following warm-blooded animals evolved twice as much carbonic acid at the freezing point as at a high temperature. He gives his observations in the subjoined table. The observations of temperature are supposed by Dr. Reid to be measured by the centigrade scale:—

	CARBONIC ACID PRODUCED, The surrounding temperature being		
	At the freezing point.	From 15^0 to 20^0 (59^0 to 68^0.)	From 30^0 to 40^0 (86^0 to 104^0.)
	Grammes.	Grammes.	Grammes.
By a Canary.....	0.325	0.250	0.129
a Pigeon	0.974	0.684	0.366
two Mice.....	0.531	0.428	0.268
a Guinea Pig	3.006	2.080	1.453

It is ascertained, then, that the respirations are accelerated in the higher warm-blooded animals by external cold; that the amount of carbonic acid then evolved is increased; and that thus the standard of animal heat is maintained, notwithstanding the diminished temperature.

Thus, if the external temperature be ... } 90°, the standard of animal heat.. } 100°, the excess is only 10°.
While if ,, 32°, ,, 100°, ,, 68°.

It is a matter of necessity that a greater amount of animal heat must be evolved by the animal, through the medium of respiration, at a low than a high temperature.

Effects of extreme and continued cold on the Respiration of the Warm-blooded Animals.

We have already seen that a moderately low temperature will eventually destroy certain imperfect young animals, the cold first accelerating respiration, but the respiration being insufficient to maintain the standard of animal heat. The temperature of the creature gradually diminishes; after a considerable period lethargy comes on—the movements of the animal diminish and cease—the respirations diminish and cease—and the animal dies, unless it be exposed to warmth.

Dr. Edwards observed the effects of extreme and moderate

temperature on the vitality and respirability of kittens in the following manner:—

He immersed and asphyxiated kittens in water at	32°	They ceased to give signs of sense and motion in ...	4′ 33″
,, ,, ,,	50°	,, ,, ,,	10′ 23″
,, ,, ,,	68°	,, ,, ,,	38′ 45″
,, ,, ,,	86°	,, ,, ,,	29′
,, ,, ,,	104°	,, ,, ,,	10′ 27″

Thus kittens lived more than eight times as long in water at 68° than at 32°, and nearly four times as long in water at 68° than at 104°. Thus a moderate temperature promotes the duration of life, while either a very cold or a very warm temperature excites augmented respiratory and other movements, and speedily exhausts vitality.

Sir Astley Cooper put a kitten, six weeks old, into water kept at at 32°.5 by means of ice. The mouth was above water. It died at the end of sixteen minutes. Its nose, lips, and gums, which were previously pallid, soon after immersion became of a beautiful vermillion colour. During almost the whole of the first five minutes it laid quiet in the water; it struggled violently during the second five minutes; between the tenth and the sixteenth minutes it laid quietly. It breathed first quickly then laboriously, and lastly at long intervals, when it died. Upon introducing a thermometer, immediately after the last breath, into the chest, it stood at 52°. The heart did not act. The blood was of a florid red in the left side of the heart. When touched the heart acted; but it was quite motionless unless thus stimulated. The peristaltic action of the bowels continued.

An hour and thirty-five minutes after its apparent death, warm water at 90° or 100° was poured into the chest. The heart began to act, and continued to do so for more than two hours, four hours, therefore, after the chest had been laid open.

In this experiment the intense external cold at first stimulated the circulation and excited the respiration by stimulating the afferent nerves. The sensory, the incident, and the motor functions of the nervous system were at first excessively excited, but speedily yet gradually the sensory and excitor functions of the nerves and the excitability of the muscles were exhausted—the latter being re-excited by external warmth.

Dr. Hodgkin placed a swallow, at a temperature of 106°, in a

deep glass vessel, immersed in a mixture of ice and salt. Although the bird remained quiet, its respiration soon became greatly accelerated, and its temperature, in somewhat less than an hour, was reduced about 20°.

It appears, then, that although at moderately low temperatures, the augmented respiration, excited by exposure to cold, is sufficient to counterbalance the increased loss of animal heat induced by the exposure, yet if the temperature be very low, although the respiration be exceedingly accelerated thereby, the heat evolved by the augmented respiration is quite unable to compensate for the heat extracted by the exposure to cold, and the body, consequently, becomes colder and colder. The increased respiration retards the cooling but does not prevent it. The smaller the animal the greater in proportion is the rapidity of cooling. In the unequal struggle to compensate for this disproportionate loss of warmth, the smaller animal has its respiration much more accelerated than the larger animal.

The recent researches of Regnault, confirming those previously made, show that, in connexion with their greater rapidity of cooling, all the smaller warm-blooded animals consume much more oxygen, in fact, respire more than the larger animals. Thus,

A young greenfinch, weighing	17.5	grammes,	consumes in the hour	1.405	Per cent of	
An adult ditto,	,,	25.	,,	,,	1.300	the weight
Crossbeak,	,,	28.6	,,	,,	1.097	of its body
While a fowl,	,,	20.22	,,	,,	0.0935	of oxygen.

We thus see that the greenfinch consumes during respiration fourteen times as much oxygen, in proportion to the weight of its body, as the fowl.

Sir Benjamin Brodie classes the effects of cold in the following order :—"1. It lessens the irritability and impairs the functions of the whole nervous system. 2. It impairs the contractile powers of the muscles. 3. It causes contraction of the capillaries, and thus lessens the superficial circulation, and stops the cutaneous secretion. 4. It probably destroys the principle of vitality, equally in every part, and does not exclusively disturb the functions of any organ."

Chossat and Prevost found that when death was occasioned by exposure to artificial cold, the temperature of the body at the time of death was very variable,—sometimes 78°.8, but on one occasion it was as low as 62°.6. These experiments were most probably

made on adult animals, for in Sir Astley Cooper's experiment, detailed above, a kitten, six weeks old, had a temperature of 52° in the chest immediately after death from cold. Indeed the experiments of Dr. Edwards, detailed before, show that the young will cool down much further than adults before they are destroyed by the cold. So that, although their power of sustaining animal heat is much less, their power of sustaining life at a low temperature of the body is greater than in adults.

In those suffering from exposure to cold, the accelerated breathing gradually gives place to diminished breathing, the respirations towards the end being taken at longer and longer intervals. It is not until the state of drowsiness, weakness, and torpor comes on, that respiration becomes so materially lowered.

We have already seen that diminished nervous energy, from whatever cause, whether the removal of the brain or the division of the spinal marrow, or the division of the vagi, or the action of narcotic poisons, leads to the lowering of animal heat along with the lowering of respiration. We have also seen that the cold-blooded animals are precisely those which have a low nervous energy, and that in each of those animals the amount of nervous energy is proportioned both to the generation of animal heat (as in bees) and to the acquisition of a higher temperature from without. In winter the body is cold, the nervous force dormant, respiration absent; in summer the body is warm, the nervous force energetic, the respiration active. Thus, as we have seen, is it also with the hybernating mammalia: with a low temperature, torpor creeps over them, with torpor, the gradual and complete suspension of respiration. Rouse the animal, even by excessively lowering the cold, and the exercise of nervous energy brings about augmented respiration, circulation, and temperature,—and these, in their turn, bring about a higher nervous energy. This effect of the nervous energy on respiration, circulation, and the production of animal heat, is the key to the different effects which external cold produces on the respiration, circulation, temperature, and nervous energy of the cold-blooded and the warm-blooded animals. In the cold-blooded animals the afferent nerves are not excited by the cold; on the contrary, their excitability is depressed or exhausted, the circulation is lowered, and respiration is suspended or lessened. In the warm-blooded animals the incident nerves have a higher life, are more excitable than in

the cold-blooded; the cold stimulates the sensory and excitor functions of the afferent nerves, stimulates also the circulation, and as a first step, and by a reflex action transmitted from the surface, stimulates the muscles of respiration.

The imperfect young of certain warm-blooded animals have a less developed cerebral and nervous energy, and they possess much less power of generating heat than the adult. In proportion as their nervous energy increases, their power to generate heat, and to sustain the standard of heat, independently of the parent, increases. If the young are born prematurely, the nervous energies are much less developed, and their power of evolving heat is in proportion less developed also.

Certain warm-blooded animals, as the mouse and rabbit, possessing low nervous energies, have those energies blunted by a degree of cold that will not have that effect on the more energetic mammalia, as the lion and wolf. Those possessing the lower nervous energy respire imperfectly, and evolve an insufficient amount of heat in winter, and they, therefore, require additional protection in the form of nests and burrows.

Infants prematurely born possess a low nervous energy, and a correspondingly low power of sustaining animal heat.

New-born infants, though capable of evolving sufficient animal heat if properly protected from cold, soon cool down below the standard of animal heat if their bodies be not so protected. It is important, while the body of infants is protected from cold, that the face, highly endowed with nerves of sentient and excitor functions, should be freely exposed to a fresh bracing dry air, which excites through the trifacial nerve reflex movements of respiration.

Certain adults possess a low cerebral and nervous energy. In them the evolution of heat is less perfect than in the robust, and they require greater external protection from the influence of cold.

In every one the respiration and the power of generating heat is lowered during sleep, and when the mind is engrossed by depressing passions or deep thought; at such times additional external warmth or covering is demanded.

If those who are exposed to cold be alert, cheerful, and energetic, they resist the external cold by the increased evolution of animal heat; but if they become depressed or drowsy, and especially if they fall asleep, then their power of evolving heat is lowered, and

they can no longer resist the low external temperature, they therefore part with animal heat, and sink accordingly.

M. Chossat has shown that at the period when death takes place from inanition, the temperature of the body is much lowered, is, in fact, lowered to the same extent that it is when death takes place from exposure to cold. The average temperature of the body at the time of death from inanition, in forty-one animals, was 77°,—of these, eighteen had a temperature varying between 64°.4 and 75°.2 at the time of death. All of these animals died with the identical symptoms of death from exposure to cold. The great lowering of temperature did not take place until the last day of life, and then not until the time of stupor. During the last six hours, the average number of respirations in six dying turtle doves was 25 in the minute, while the average number in healthy turtle doves is 49. The respirations, after having become gradually slower and slower, sometimes become, just before death, more and more distant and insensible, sometimes, on the contrary, they become excessively accelerated and panting.

Under the influence of inanition the creature is tranquil at first, then it becomes agitated; on the last day the agitation gives place to general feebleness and a state of partial stupor. The animal becomes more and more feeble, the respiration slower, sensibility and the excitability of the incident nerves diminish, often the eyelids, half open, do not close when touched, complete stupor is established, and death takes place, sometimes in a calm and tranquil manner, sometimes with slight convulsions, and sometimes with tetanic rigidity of the body.

This, which is the history of the last day of inanition, is the history also of the last stage, just before death, from exposure to cold.

Napoleon's retreat from Russia, and similar events, have shown that towards the close of life, under the destructive influence of cold, the senses are benumbed, the muscular power is weakened, torpor comes on, the respirations become slower and slower, and death ensues. Sometimes death is preceded by muscular tremor, sometimes by tetanic convulsions and muscular rigidity.

Under the influence of external cold, the circulation at the surface is at first roused, the sensory and incident nerves are stimulated, the respirations, by a reflex action, transmitted from the excited cutaneous nerves, are accelerated, and an increased amount of

animal heat is evolved. If the cold be not excessive, the quickened respiration and augmented evolution of animal heat are permanent, and the creature maintains the standard of animal heat. If, on the other hand, the cold be excessive and continuous, the excitability of the sensory, excitor, and motor functions becomes lessened and exhausted, the circulation in the capillaries is diminished and arrested, the muscular powers are enfeebled and exhausted, mental energy gives place to drowsiness and torpor, the respirations become slower and slower, the animal heat sinks rapidly, and death ensues, either with the simple cessation of respiration, with convulsions, alternating with relaxation, or with tetanic convulsions and muscular rigidity.

Effects of external warmth and extreme heat on the Respiration of Warm-blooded Animals.

I continue the narrative, and relate the effect of external heat on animals expiring, or having ceased to breathe, under the influence of cold.

M. Chossat took a turtle dove which was on the point of expiring from inanition, owing to the loss of its animal heat, and exposed it to the warmth of a stove. Just before applying warmth the temperature of the animal was 73°.4. The creature was unconscious, the eyelids were open and fixed, and did not wink when irritated. Irritating the toes caused only the slightest movements of the hind limbs. Respiration was no longer appreciable.

In two minutes after applying the warmth the respirations became very marked; in six minutes the respirations were good; the creature was more animated, and it moved its head. In seven minutes winking was re-established; in ten minutes respiration was natural. In forty-three minutes the creature's life seemed re-established, and it was then left. On being again observed, after exposure to the warmth for two hours and seven minutes, it was dead; the head being thrown backwards, in a state of opisthotonos. The heat in the cloaca was 118°.4.

This experiment was repeated in twenty-five birds, when on the point of death from inanition. Food was given to them and three recovered; the rest died. Eight died in convulsions. In these there was a progressive diminution of sensibility and muscular

force; they became drowsy, and at length lay extended. The successive attacks of convulsions which came on were sometimes violent, sometimes slight, and generally accompanied with opisthotonos. There was usually complete relaxation between the attacks; sometimes there was a general rigidity of the body, which usually indicated death.

Dr. Edwards found that when the young imperfect mammalia appeared on the point of expiring, some being, indeed, motionless and apparently dead, from exposure to cold, he easily restored animation by placing them before a fire. He cooled birds which were almost entirely fledged, so that they became very weak, and seemed ready to expire. These recovered as rapidly as the younger birds, when warmed artificially, but the recovery was only temporary, since they mostly died in one or two days.

John Hunter observed that when intense cold had forced blackbirds to take shelter in out-houses, such of them as had been caught, and were, from an ill-judged compassion, exposed to a considerable degree of warmth, died very soon. The death, he remarks, was owing to the degree of heat being increased too suddenly for the proportion of life remaining in the animal. Warmth causes a greater exertion of the living powers than cold; and an animal in a weakly state may be obliged by it to exert a quantity of the action of life sufficient to destroy the very powers themselves. These remarks of John Hunter's cannot be borne too strongly in mind in attempting to recover those almost or apparently dead from exposure to cold.

Sir Astley Cooper opened a snake, rigid and supposed to be dead, after having been immersed in alcohol. The heart was beating, and it showed some voluntary power. He put it into cold water, and the heart's action became languid and slow. It was then thrown into warm water, the action of the heart became quick and vigorous, and it began to move freely, recovering its voluntary power. It was then returned into cold water,—its voluntary power lessened, and its heart acted less frequently and vigorously.

Mr. Barlow relates,—"I decapitated an eel. I observed gaspings in the separated head, which ceased after a time. I now introduced my finger into the mouth, and pushed it into the posterior part of it, but failed to excite the act of deglutition, which would have followed had the excito-motory principle been vigorous. It struck

me that I could restore the reflex actions by the use of warmth; and therefore I put the head into water of about the temperature of 90°. Then there appeared frequent and energetic gaspings, and the act of deglutition could be induced by the same stimulus which was perfectly fruitless previous to the immersion." In this interesting experiment gaspings were re-induced by the external application of warm water, which restored the excitability of the incident nerves, and then excited reflex actions, after the functions of the nerves had been exhausted by comparative cold.

Cold, which at first stimulates the reflex functions, at length exhausts the excitability of those functions, while warmth restores their excitability; but we must bear in mind John Hunter's experiments, and the pregnant examples afforded above in the treatment of narcotic poisoning. We must recollect that warmth, after restoring, may again exhaust—may even altogether annihilate the vitality of the excitor functions. In rousing the excitability of the reflex function we must not exhaust and annihilate it by the over use of one stimulant, such as warmth. Employ warmth in the degree suited to the remains of vitality; do not prolong it—but, alternate with the warmth, some other stimulant, even cold itself, or friction, or ammonia, or even electricity; whatever is done, however, must be proportioned to the remains of vitality. It is not the object to get a quick revival, ending most probably in fatal collapse, but to get a permanent recovery. In rousing the excito-motor, we should attempt to rouse also the higher sensory functions, that so we may rouse the brain, one great fountain of nervous energy, and through it, of circulation, of respiration, and of the evolution of animal heat.

If the surface be exposed to a high temperature, the respirations are augmented in fulness and frequency. Mr. Barlow informs me that in descending into a warm bath, at a very high temperature, he can at first restrain the respirations; but when the warm water covers a greater extent of surface, respiration is increased in spite of the efforts of the will. Here the reflex function, highly excited, overpowers volition, and respirations, full, frequent, and in continued succession, are excited, reflexly, by the warmth applied to the surface acting on the incident nerves and on the capillary circulation.

Delaroche and Berger exposed a cat, a rabbit, a pigeon, a yellow

hammer, and a large frog, to a dry heat of 108°.5 to 112°; the greater number at first remained undisturbed, but in about half an hour they became agitated, and their respiration was progressively accelerated until it became panting. There was then a remission of the symptoms in almost all the animals. They remained exposed to the high temperature an hour and a half, and in half an hour afterwards they recovered. They were subsequently put into a stove at 133°.25, rising to 149°. All, except the frog, perished at various periods, varying from twenty-four minutes to one hour and fifty-five minutes.

The heat at the surface excites accelerated reflex acts of respiration, which tend to counterpoise the heat that excites them. The accelerated respiration increases evaporation, and becomes a cooling process. The same experimenters, as has been already stated, at p. 189, found that a wet sponge, a frog, and a damp porous jar, when placed in a stove at 126° to 140°, remained at a temperature of about 100°.

Under the influence of a moderate temperature the respirations are not so quick, and the generation of carbonic acid, and evolution of animal heat, are not so great as they are under the influence of a lower temperature. If the temperature be high, especially if applied through the warm bath, and still more if it be very high, the respirations are greatly accelerated; but the evolution of animal heat, by the formation of carbonic acid, is more than counterbalanced by the increased evaporation from the lungs. The heat acting on the surface accelerates the respiration by a reflex action.

If the heat be excessive, and long continued, the excitability of the nervous system and the vital energies become exhausted—debility, drowsiness, and torpor come on, the respirations cease, and death ensues, often, it would appear, with tetanic convulsions.

If the circulation and respiration, the excitability of the reflex and sensory functions of the nervous system, the contractility of the muscles, and the cerebral energy be enfeebled or exhausted by long-continued external cold, or by cold induced by inanition, the application of external heat restores circulation and respiration, the excitability of the reflex and sensory functions, the contractility of the muscles, and the cerebral energies; but in the adult animal, if the exhaustion from cold be excessive, and the application of

external heat be long continued, and disproportioned to the vital energies, all those functions become again exhausted, and unless they are again restored, death ensues.

Let us once more trace the order of phenomena in which cold acts to accelerate and then retard respiration, and in which warmth re-accelerates and then again retards respiration.

Cold, when first applied, stimulates the circulation in the cutaneous capillaries, stimulates the sentient and excitor functions of the afferent nerves of the surface, and augments and accelerates respiration by a reflex action transmitted from the excitor nerves of the surface.

After being continued for a time, cold diminishes the capillary circulation, blunts sensation, depresses the excitor functions, diminishes and retards respiration, and lowers the animal heat.

At length the continued cold arrests the circulation in the capillaries, destroys sensation and consciousness, exhausts the excitor functions, and finally puts a stop to respiration, the animal heat being lowered from 20° to 30°.

If external warmth, either in the bath or before a fire, be applied immediately, or very soon after respiration has been arrested by cold, it renews the circulation in the superficial capillaries, restores the excitability of the incident nerves of the surface, re-excites respiration through the reflex function, and at length re-instates sensation and consciousness.

If the warmth be continued and moderate, circulation, respiration, the excitor, sensory, and motor functions of the nervous system, and the cerebral energies, are restored to their normal standard.

If, however, the continued heat be excessive, then torpor again comes on, the respiratory and nervous functions are again exhausted, and death ensues, often, apparently, with convulsions.

Influence of External Cold and Heat on the Circulation, and of the Circulation on Respiration.

We have just seen that in the cold-blooded animals external cold diminishes and at length arrests respiration, and depresses and almost arrests the circulation, while external warmth increases the circulation and excites respiration; and that in the active warm-blooded animals moderate cold excites increased respiration and

circulation, while moderate warmth causes diminished respiration and circulation. The circulation as well as the respiration are excited or depressed by changes in the external temperature. Not only so, but the circulation in the capillaries is affected before the respiration. If the energies of the nervous system, especially of the nervous centres, be low, as in cold-blooded animals, external cold depresses the circulation, at the same time that it depresses sensation and consciousness. If, on the other hand, the nervous energies be high, as in warm-blooded animals, the cold, up to a certain point, stimulates the circulation. If the nervous energies of the bee are roused when it is disturbed during the winter, its circulation becomes augmented. If, on the other hand, the nervous energies of the warm-blooded animal be blunted; if, for instance, it become sleepy or torpid, or pass into profound hybernation, then external cold causes depression of circulation in proportion to the depression of the nervous energy. If, however, the cold be so intense as to rouse the nervous energies, the circulation is then stimulated and augmented. If the nervous energies be lowered by inanition, circulation and respiration are lowered; and if sleep or torpor be superadded to inanition, then the circulation is proportionately still farther depressed. If the surface be suddenly exposed to cold, the peripheries of the nerves are excited, sensation is roused, and the capillary circulation is at the same time also roused; if the external cold be continued, sensation is blunted, and the superficial circulation lowered.

That the increase or diminution of the circulation is due to an action in the capillaries, and not to an action in the heart, is certain, since, if one arm be exposed permanently to cold, and the other to warmth, the circulation in one will be depressed, in the other maintained or exalted, and yet the same heart propels the blood through the blood-vessels of both limbs.

If the whole chain of instances be noticed, it will be observed that the excited or depressed circulation in the capillaries is connected with, and caused by, an excitement or depression of the peripheral nerves; the excitement of those nerves stimulating the capillary circulation, and the depression of those nerves lowering the capillary circulation. The same effects on the circulation are in fact induced, in whatever way the nerves be affected, whether they be stimulated or depressed by external agents, as cold, galvanism, or irritants, or by internal emotions, as rage or fear.

The palpable effect of depressing cold is to shrivel the surface, and to cause constriction of the superficial capillaries; exciting cold, on the other hand, renders the skin ruddy and the capillary circulation more vigorous; in one instance, less blood, and in the other, more blood than usual is admitted into the capillaries.

Warmth causes an increase in the quantity of blood in the surface, and general relaxation of the capillaries.

The circulation of the blood exercises a vivifying influence on the functions of the nervous system. Cut off the supply of blood from a limb, and motion, sensation, and the excito-motor functions of that limb are gradually paralysed; restore the circulation, and the functions of the nerves of the limb are gradually restored. The energy of the whole nervous system, both of the centres and the peripheries, is in proportion to the activity of the circulation. Wherever the incident nerves are numerous, "the fibres are in close approximation with a vascular plexus."

When the blood circulates freely in the organism its presence serves as a stimulus to the afferent nerves; increased respiration being excited by a reflex action. On the other hand, when the circulation in the capillaries is diminished, the incident nerves are depressed, being deprived of the vitalising stimulus of the blood, and respiration is diminished or even arrested.

In the numerous instances previously given, in which respiration was immediately influenced by external agents applied to the surface, the respirations were manifestly affected through the medium of the excitor functions of the afferent nerves, the spinal marrow, and the reflex motor functions of the efferent nerves. In many of the instances the impression on the surface which excited respiration, excited also sensation, and it can scarcely be denied that here the sensory functions of the afferent nerves may have co-operated with the excitor functions in inducing respiration. In many of the instances, however, consciousness and sensation were absent, and yet the external stimulus produced the same effect on the respiration as if sensation were active. It is certain that in these cases the respirations were caused by the excitor functions of the nerves alone, the sensory functions being suspended. In fact the respirations were caused and influenced by a power which existed when sensation was present, and which existed also when sensation was absent, by a

power which operated during sleep, sopor, lethargy, hybernation, and coma, as well as during active sentient life. While it is certain that in all these instances the respirations were excited through the reflex function of the nervous system, it is not proved that they were in any instance excited by sensation. In fact it is the necessary characteristic of respiration that it shall persist when sensation is suspended, else life itself would be dependent on consciousness.

Consensual Respiratory Movements.

While respiration is carried on in the absence of sensation there are some of the phenomena of respiration which seldom exist when sensation is absent, and which are excited by external impressions; among such phenomena are laughter, crying, and coughing.

Laughter may be excited by tickling the soles of the feet, the arm-pits, and in some highly and even morbidly impressible persons, by tickling any part of the surface of the body. I have a patient now under my care affected with symptoms referable to affection of the nervous centres, probably of the corpora quadragemina and adjoining parts; the pupils are small, sensation and motion are somewhat impaired. In this case, at a time when the limbs were unusually deficient in power, uncontrollable laughter was excited by the gentlest percussion over any part of the body; subsequently, when the muscular powers were greater, the surface could be freely percussed anywhere without exciting laughter. In hysterical persons the surface is morbidly sensitive, and in them hysterical laughter may sometimes be induced by merely touching the more sensitive parts of the body. I believe that in such instances laughter is in great part excited through the medium of sensation. Dr. Carpenter and Dr. John Reid have instructively illustrated the subject of the movements excited through the medium of sensation, movements happily classed as consensual by the former physiologist. Those respiratory movements due to sensation are evidently excited in a reflex manner, but such reflex movements differ essentially in character from reflex movements of the true spinal system. When the excito-motor functions are performed, the spinal marrow is the centre of the nervous arc formed by the afferent and efferent nerves. The spinal marrow merely transmits the impression from the excitor to the motor nerve,

and is not itself necessarily stimulated to an independent centric action. It appears to me that the consensual reflex movements, such as laughter excited by tickling, are not the result of the mere transfer of the nervous force through the higher nervous centre from the afferent sentient nerve to the efferent motor nerve. I conceive that the nervous centres, probably the corpora quadragemina and adjoining structures, are roused to independent action by the stimulus applied to the afferent nerve; that the nervous centres, thus stimulated from the periphery, now act as a centric force, exciting, in the instance under consideration, laughter, by stimulating the associated motor nerves, not so to speak, reflexly, but directly; just, in fact, as laughter is excited by certain humorous or ludicrous ideas; the mental emotion stimulates the nervous centre, which, in its turn, stimulates the associated motor nerves.

Laughter may exist during both the hysterical and the epileptic fit, when there is complete unconsciousness; but if the soles of the feet be tickled during sleep, or when sensation is paralysed, respirations and certain movements of the limbs are excited, but laughter is not excited. We thus see that when we stimulate the excitor functions only of the nerves supplying the soles of the feet, reflex movements are excited, but not the movements of laughter, while, when the sensory as well as the excitor functions of those nerves are stimulated, laughter is excited. I conceive that the conclusion is forced upon us that laughter, which is an interrupted, violent, expulsive respiratory act, when it is excited by tickling the surface, is due in great part to stimulation of the sensory functions of the nerves, and the consequent excitement of the nervous centre, and probably in part also to the co-operation of the excitor functions of the nerves.

When laughter is extreme the inspiration is crowing, owing to the noisy approximation of the vocal chords.

Smiling may be excited, as Dr. Hartley says, by gently touching the cheek of the child, it may also be excited by tickling the sole of the foot, so slightly as to be within that degree of tickling which would excite laughter. Smiling is essentially an inspiratory action, being an enlargement of the oral aperture for respiration; but while inspiration is perpetually being interrupted by expiration, and then again renewed, smiling is for a time continuous, whether excited by tickling or by a pleasing mental emotion. Smiling frequently

exists with complete unconsciousness; indeed, it customarily takes place towards the end of the hysterical and the epileptic fit, before the restoration of consciousness. I believe that smiling may be excited in the infant by gently stroking the cheek, even when sensation is absent; if this be so smiling may be induced by stimulating the excitor functions of the afferent nerves. I consider that smiling, like laughter, is essentially excited in the higher nervous centres. It is the characteristic of the act of smiling that it is continuous. This, as I shall have another occasion to show, is the characteristic of the actions excited in the nervous centres; they are thus readily contra-distinguished from the excito-motor or reflex actions—for while the former are essentially continuous, the latter are essentially intermittent, being perpetually interrupted and renewed, with the interruption and renewal of the excitor stimulus.

Crying is a phenomenon of respiration, which, like laughter, is seldom excited excepting in connection with sensation. While a pleasurable or tickling sensation excites laughter, a painful sensation may excite crying. In the young, and in those not trained to repress the emotions, pinching, cutting, or burning the skin, or otherwise causing pain, excites crying. Crying is a forcible expiratory act, accompanied by noisy approximation of the vocal chords. Owing to their approximation, the glottis is narrowed, the air is expelled slowly, and the expiration is prolonged. Groaning is a modification of crying, is excited by less active pain, and is often the irrepressible expression of those who can and do repress crying. Crying is frequently present when the person appears to be unconscious. The exposure of the new-born infant to cold excites a deep inspiration, followed by crying. In this case sensation is almost or altogether absent, and the crying is manifestly caused by the excitor functions only of the afferent nerves. Although crying is usually excited in connection with sensation, it is not so closely dependent as laughter on the sensory function of the afferent nerves. Usually both the excitor and sensory functions of the afferent nerves coincide in exciting crying, but sometimes the excitor, sometimes the sensory, function predominates.

Sobbing is caused by the repeated contact and noisy separation of the vocal chords during the inspiration which precedes crying.

Sometimes when pain is felt from any cause, but when it excites neither crying, groaning, nor sobbing, it occasions a sudden deep

inspiration. Probably, in this instance, the inspiration is caused by the excitor function of the afferent nerves.

Coughing is frequently excited quite independently of disease in the lungs, by the mere exposure of the skin to cold. This occurs in persons who are morbidly sensitive to the influence of cold. A hard, dry, unproductive, troublesome cough is excited in them, when they get into bed between cold sheets, or leave the warm bed in the morning and expose the general surface to the cold air, or put their feet on the cold ground; when they leave the house on a cold raw day; when they are exposed to draughts of cold air; whenever, in short, the skin is exposed to a sudden transition from warmth to cold. In these persons, instead of the skin becoming ruddy and glowing under the bracing influence of moderate cold, it becomes cold and shrivelled; instead of the inspirations being increased in fulness they are shortened and interrupted by a frequent cough. The employment of Dover's powder in these cases usually increases the capillary circulation, blunts the morbid sensibility of the surface, and checks the cough.

Many hysterical persons, who possess a highly sensitive surface, cough under similar circumstances. Frequently these persons are subject to a constant cough when awake; this cough is aggravated by external exposure, and by any mental emotion that may exalt still more the morbid sensibility of the skin. In these persons belladonna and henbane, in combination with tonics and other means, lower the morbid sensibility of the skin, increase the capillary circulation, and subdue the cough.

It is not usual for cough connected with morbid or exalted sensibility of the skin to come on during sleep; cough, however, does come on during sleep in other cases, and it may undoubtedly be excited quite independently of sensation by irritation of the larynx. In such cases cough is caused by the excitor functions of the superior laryngeal nerve. In that class of cases of which I am now speaking, connected with undue sensibility of the skin, the cough is, I conceive, excited both through the sensory and the excitor functions of the afferent nerves, and it is checked by invigorating the tone of the skin by friction, and by subduing the morbid sensibility by narcotics. It is to be observed, that in these cases the morbid sensibility is coincident with a lowered tone of the surface, and an enfeebled constricted capillary circulation;

and that as the lowered tone is invigorated, and the constricted capillary circulation rendered free and normal, the same stimulus to the surface which previously excited cough then excites free deep respirations.

Effects of External Stimulus on the Expulsive Actions.

Under certain circumstances the expulsive actions, such as vomiting, the voiding of fœces and urine, and the act of parturition, may be excited by undue or morbid stimulus to the skin, especially when the contents of the stomach, the rectum, the bladder, or the womb are abundant and ready to be expelled. Extreme external cold after a full indigestible meal may excite nausea and vomiting. The inclination and effort to expel the fœces are often excited by the exposure of the nates to the cold air. On first getting out of bed there may be no inclination to void urine, but on baring the surface to the cold air, the inclination is speedily excited. The flagging action of the uterus in expelling the fœtus, the placenta, or clots of blood, is often roused to efficient expulsive contractions by dashing cold water on the surface, or by exposing the surface to a current of cold air. This subject has received important illustration from Dr. Tyler Smith.

When the expulsive power over the rectum or bladder is feeble, one of the most certain and valuable means of augmenting that power is to rouse the tone of the skin habitually and healthily by external stimulants and friction. It is to be observed that the application of the stimulus to that part of the surface adjoining the viscus to be emptied has more effect on that particular expulsive act than its application to any other part; thus the cold dash over the abdomen rouses the expulsive powers of the bladder and uterus, while cold to the nates excites the evacuation of the fœces. It is an interesting practical illustration of this subject, that in cases of poisoning by opium, after repeated and powerful emetics have failed to excite vomiting, the dashing of cold water on the surface has often immediately led to the forcible expulsion of the poison, the food, and the emetics contained in the stomach. Two interesting illustrations of this are given at pp. 226 and 227.

Excitement of Respiration by Stimulus to the Mucous Membranes.

Professor Müller, by a happy generalisation, has shown that irritation of the mucous membranes induces acts of expulsion, which are performed by the muscles of expiration. If any particular mucous membrane be irritated an expulsive action is excited, bearing usually on the region irritated.

If the mucous membrane of the nostrils be stimulated, sneezing, an expulsive effort clearing out the nostrils, is excited; if the mucous membrane of the larynx, trachea, or bronchi be stimulated, cough, an expulsive action clearing the larynx and trachea, is excited; if the fauces, pharynx, or stomach be stimulated, vomiting is excited; if the rectum be stimulated, expulsion of the fœces is excited; if the bladder be stimulated, expulsion of the urine is excited; and if the vagina or uterus be stimulated in the latter stages of pregnancy, the expulsion of the fœtus is excited.

In all these instances, especially if the act of expulsion be powerful, the expiratory effort forms, in whole or part, the expulsive power. I say the expiratory effort, not the act of expiration. The muscles of expiration are all excited to violent action, but owing to the closure of the glottis, or of the higher respiratory apertures, the expiratory expulsion of air from the lungs is arrested. If sneezing be excited the pressure of the tongue and the palate against the back of the fauces prevents the expiration, and the sudden removal of the obstruction permits the violent expiratory action to flush the obstructed nostril. If coughing be induced, the glottis is at first closed, and then suddenly opened by the noisy separation of the vocal chords, and the sudden and forcible expiration that follows expels from the larynx any obstructing secretion. If vomiting be excited the larynx is drawn forwards and pressed upwards under the base of the tongue, so as to prevent the egress of air from the lungs: all the apertures of expulsion are closed except those leading from the stomach; the stomach is compressed in front by the expiratory contraction of the abdominal muscles, and, singularly enough, from above and behind, by the descent of the diaphragm, that muscle exchanging its inspiratory for an expulsive action. If the fœces be expelled while every other outlet of expulsion is closed, the sphincter ani is relaxed, the anus

is opened, and all the expulsive efforts of the expiratory muscles bear upon that aperture. In like manner with micturition, and in like manner also with the expulsive pains of labour, for the physiological account of which I refer to the work of Dr. Tyler Smith. In each of these instances some individual opening or sphincter is relaxed, and the expiratory muscles are roused to action, through the excito-motory functions, so as to bear alone upon that opening, the respiratory and every other aperture being closed.

It is to be observed that all the expulsive actions are usually preceded by a deep inspiration. The increased quanity of air in the lungs gives a better purchase and greater force to the expiratory muscles of expulsion. It follows from this that the stimulus applied to the mucous membrane excites reflexly a deep inspiration, followed by a violent expulsive effort; the expulsive effort being the object of the whole action.

Of the various acts just spoken of, which may be excited by stimulating the mucous membranes, and which involve the employment of the respiratory muscles, sneezing and coughing are more particularly respiratory acts.

Sneezing is excited in health by tickling or irritating the nostrils. In those who have "a cold in the head" sneezing may come on spontaneously, being excited by the morbidly sensitive or excitable state of the nasal mucous membrane. Sneezing is almost always performed by the healthy person in connexion with excited sensation. When it occurs spontaneously, from an irritable state of the nostrils, it sometimes takes place during sleep; this is evidenced in a little girl now under my care, affected with bronchitis. Although sneezing may evidently be classed among the consensual movements, yet, in some instances, it appears to be caused solely by stimulating the excitor functions of the afferent nerves of the nostrils, and probably it is always, in part at least, an excito-motory phenomenon. When sneezing is excited by a strong light irritating the eye, it is probably in great measure due to excited sensation.

Cough, excited by irritation of the larynx, trachea, or bronchial tubes, does not differ in mechanism from cough excited by the exposure of a sensitive skin to cold. In the latter case the cough is almost always connected with excited and depraved sensation, and is only brought on when the person is conscious: in the former,

although it is usually excited only during the waking state, yet it often occurs when the patient is asleep. It is manifest that the cough, in these instances, is caused by stimulating the excitor functions of the superior laryngeal nerve in the larynx, or of the par vagum in the bronchial tubes.

The superior laryngeal nerve, in its excitability to impressions, presents some remarkable and interesting phenomena. Although the mucous membrane of the larynx appears often to be but comparatively slightly irritated by such caustics as the nitrate of silver, yet pure carbonic acid excites instantaneous and complete closure of the glottis. The superior laryngeal nerve would appear indeed to be specially and highly endowed with excitor functions, and yet comparatively but slightly with sensory functions. In this respect that nerve, as well as most of the nerves distributed to the mucous membranes, differs from the afferent nerves distributed to the skin, for those nerves, as we have already seen, are both exquisitely sensitive and highly excitor.

The superior laryngeal nerve is so endowed as to be the guardian of the glottis, and, through it, of the lungs. While carbonic acid, a gas immediately poisonous to the blood, excites, when pure, closure of the glottis, nitrous oxide, hydrogen, and nitrogen, gases not immediately poisonous, though incapable of supporting respiration, do not excite closure of the glottis. Carbonic acid, when pure, nitric oxide, and other poisonous gases, are consequently irrespirable, whereas nitrogen, hydrogen, and nitrous oxide are respirable. The inestimable life of Sir Humphry Davy was saved by this guardian function of the superior laryngeal nerve; for when he attempted to inspire nitric oxide, the stimulus of that gas caused instant closure of the glottis, and the great philosopher escaped; his mouth and fauces only being scorched by the acrid nitrous acid fumes.

It is an interesting fact, that while the superior laryngeal nerves prevent, by the closure of the glottis, the ingress to the lungs of the poisonous gases, they often do not prevent the ingress of air charged with irritating particles; thus the Sheffield knife-grinders can breathe an atmosphere charged with steel dust, which causes in time fatal disease in the lungs; and pulmonic patients can breathe air charged with finely powdered nitrate of silver.

The closure of the glottis, just spoken of, takes place during

inspiration, and is usually silent. If the closure be incomplete, the vocal chords being approximated in the vocalising position, the inspiration is stridulous or whooping.

There is a morbid modification of the excitor functions of the superior laryngeal nerve with which it is practically important to be acquainted. Many persons who have no affection of the lungs or heart, are subject to dyspnœa and palpitation if they walk quickly, run, or ascend a flight of steps. This is due to a deficiency in the muscular control over the glottis. In health the vocal chords are drawn asunder during each inspiration, so as to widen the glottis; the extent to which the glottis is widened being exactly proportioned to the volume of the inspiration and the extent of the inspiratory muscular effort. The persons of whom I now speak want this power; they cannot expand the glottis in proportion to the inspiratory effort; in consequence of this the glottis is narrow, and is still farther narrowed by the effort of inspiration, the column of inspired air tending by its pressure to push the vocal chords nearer to each other; an adequate supply of air cannot enter the lungs through the narrow glottis, and dyspnœa and palpitation are the result. The glottis is thus narrowed in persons having an inflamed or irritable larynx; in those affected with hysteria, or with a morbidly sensitive surface and exalted excito-motor functions; and in those also who are deficient in excito-motor power.

In those in whom the excito-motor functions are morbidly exalted, and in those also in whom those functions are enfeebled, the balance of excito-motor power is restored by the same remedial means; I allude to the effect of the general stimulation of the surface by dashing on it cold salt water, and by external friction. These means excite healthy deep inspirations, in which the glottis is expanded in harmony with the inspiratory efforts. It is to be observed that the same phenomenon, deficiency in the circulation through the cutaneous capillaries, may produce in one person exquisite sensibility and an exalted or depraved excito-motor function of the nervous system, and in another, blunted sensibility and enfeebled excito-motor function. It is also to be noticed that in the same person diminution in the capillary circulation at the surface, under the influence, for instance, of external cold, will at first exalt, then depress, and if the cold be long continued and intense, at length extinguish the sensory and excitor functions.

In all such instances, in the order of the phenomena, the sensory cease before the excitor functions of the peripheries of the afferent nerves; hence the respirations, excited by the reflex functions, may be carried on for an indefinite time during complete anæsthesia, if the influence exhausting the peripheral functions of the nerves be not too great.

If a person attempt to inhale either the undiluted vapor of ether or chloroform, or pure carbonic acid, inhalation is instantly and completely prevented by the silent closure of the glottis. If the vapor or gas be copiously diluted with air, the mixed atmosphere can be respired freely. If only moderately diluted, inspiration may be sometimes silent and free, sometimes stridulous and difficult, owing to the noisy approximation of the vocal chords, or it may be suddenly checked by closure of the glottis, followed immediately by a noisy cough; the closure of the glottis and the cough being excited in a reflex manner, owing to vapour or gas stimulating, through the mucous surface of the larynx, the excitor functions of the superior laryngeal nerve.

We thus see that a stimulus applied in the larynx to the superior laryngeal nerve, may excite during inspiration, according to its degree, either complete closure of the glottis, stridulous inspiration, or narrowing of the glottis; while during expiration it may excite cough, the cough being hard, dry, and unproductive, or easy and followed by expectoration, accordingly as mucus or a foreign body is present or not in the larynx.

If the sputa be tenacious and tough, or glazed and frothy, or stringy, the expectoration is difficult, the cough long-continued; the sputa not being expelled all at once, but by a series of repeated efforts. If the sputa be in rounded nodules, each portion is expelled by a single easy cough; sometimes, indeed, such sputa are expelled unconsciously and without effort. Bloody sputa, especially the rusty, sticky sputa of pneumonia, are usually only expelled by a repeated, laborious, and troublesome cough; but pure blood is often, curiously enough, expelled through the larynx from the bronchial tubes in large quantities, without exciting any cough, and with comparatively little expulsive effort; with an expulsive effort, in fact, which often appears to be, and may easily be mistaken for that kind of vomiting by means of which the clear secretions of pyrosis are expelled.

If the sputa cling to the vocal chords, and are with difficulty expelled, they excite not only cough but also narrowing of the glottis, owing to the approximation of the vocal chords. Thus the dyspnœa occasioned in bronchitis by the obstruction to inspiration caused by the presence of mucus in the bronchial tubes, is increased by the additional obstruction caused by the narrowing of the glottis.

Irritation of the larynx tends to excite narrowing or even closure of the glottis, both during inspiration and expiration. If the sputa loiter in the larynx, or if the cough, though dry, be troublesome, the glottis is usually narrowed. In whooping cough it would appear as if the crowing inspiration were occasioned by the irritation in the larynx, caused by the previous severe cough. Public speakers are sometimes affected, when fatigued by long speaking, with stridulous inspiration in the manner pointed out by Mr. Bishop. Laughter often appears to excite crowing inspiration, and crying frequently gives rise to sobbing. Indeed it appears that any stimulus that may excite closure of the glottis during expiration may also excite silent or noisy approximation of the vocal chords, or closure of the glottis, during inspiration. Thus, pain at the surface, or a plunge into a cold bath, may excite in the young both sobbing and crying. Tickling the feet may excite both crowing inspiration and laughter. Irritation to the surface of persons susceptible of the application of cold may excite both stridulous inspiration and coughing.

While it is amply proved that cough may be excited by stimulating the superior laryngeal nerve through the medium of the mucous membrane of the larynx, the proof is not so extensive which shows that coughing may be excited by stimulating the pulmonary branches of the vagus through the medium of the mucous membrane of the bronchial tube. It is, however, sufficient.

Mr. Erichsen inserted a probe through a very small opening into the trachea; when he passed it upwards to the larynx coughing was excited, an effect which has been observed by many physiologists. He then passed the probe downwards into the bronchial tubes, and when he stimulated their surface coughing was again excited. No other experimenter, excepting perhaps Dr. John Reid, has taken the precaution, when inserting an irritating substance through the trachea into the bronchiæ, of making the tracheal opening so small that all the expired air should pass

through the larynx, and none through the tracheal opening. When this precaution is not taken, when all the expired air can rush out through the tracheal opening instead of the larynx, effectual coughing is necessarily replaced by general expulsive movements.

Haller opened the trachea and applied butter of antimony to its lining membrane; the animal tried to cry, but did not cough. In another experiment, irritation of the tracheal mucous membrane with sulphuric acid and the scalpel produced no effect. Brachet found that violent coughing was excited when the fumes of hydrochloric acid, and other irritants were passed into the bronchial tubes, before the division of the vagi; but that after their division no such effect was produced. Dr. John Reid conjectures with reason, that in these experiments the irritant reached the larynx. Dr. John Reid found that irritation of the larynx excited violent cough, but the effect ceased when he divided the superior laryngeal nerves. The same physiologist observed, that on injecting cold water into the bronchiæ, through a small opening in the trachea, in some experiments it excited coughing, in others it did not. In one instance, when cold water was injected into the tube, cough was not induced, but when alcohol was injected, efforts to cough were excited; on injecting the alcohol a second time the animal remained perfectly quiescent. In another experiment, alcohol, when first injected, excited coughing; the vagi were then divided, and the renewed injection of the alcohol produced no effect. In another experiment, after the vagi were divided, alcohol was injected into the trachea, and a drop of muriatic acid was placed in the trachea, without exciting uneasiness or cough.

I divided the trachea in a chloroformised dog (experiment at p. 219); when it had recovered consciousness, I several times passed a probe through the opening in the trachea upwards to the larynx, and I thus invariably excited strong expulsive efforts, analogous to coughing. I then scratched the surface of the trachea without perceptible effect. I afterwards passed the probe downwards, and scraped the surfaces of the larger bronchiæ, and thus excited strong expiratory or expulsive efforts, evidently analogous to cough; on renewing the friction, the expulsive efforts were renewed with more or less power.

These experiments prove, that while irritation of the interior of the larynx excites violent cough, through the medium of the

superior laryngeal nerve; irritation of the trachea causes very little effect on the respiratary movements; while irritation of the bronchiæ excites coughing through the medium of the pulmonary branches of the vagi, but the cough can neither be so certainly, violently, nor repeatedly excited by stimulating the bronchiæ as the larynx.

While foreign bodies in the bronchiæ sometimes do excite cough, sometimes they do not; when they pass backwards into the larynx they invariably cause violent cough and general struggling.

Diseases of the tissue of the lungs, involving the bronchial tubes, while they sometimes do excite cough, sometimes do not. In some cases of phthisis, pneumonia, and bronchitis, cough is not excited unless and until the sputa reach the larynx. In other cases again the cough is constant, dry, and harassing. In these the cough is doubtless excited in the bronchial tubes through the medium of the vagi; and in many cases also by the stimulus of external impressions acting on the skin, and exciting cough reflexly through the afferent cutaneous nerves, as in the instances already related.

I have already considered those cases just referred to, in which violent dry cough is excited, owing to the morbid excitability of the surface, the lungs and air passages being perfectly healthy. Analagous instances are frequent in which the same kind of cough is caused by some affection of the mucous membrane of the stomach or uterus, the lungs being themselves healthy. It may be questioned whether, in some of these cases, the cough is immediately excited by the impression on the incident nerves of the affected mucous membrane, or by the morbid excitability of the surface, which is so frequently induced by the disorders in question of the stomach or womb.

Sometimes, as in whooping cough, when the cough is violent, long continued, and fruitless, the action of coughing seems to pass into that of vomiting.

In bronchitis, with difficult expectoration, vomiting acts both to expel the food from the stomach, and the sputa from the bronchial tubes. Indeed, it is frequently to be observed, that vomiting is simultaneously an expulsive action from the stomach, and an expiratory action from the lungs, the glottis not being absolutely closed, but permitting a forced noisy stream of air to be ejected from the larynx. Owing to the forcible and continuous compression of the whole lungs, the patient ejects, simultaneously, fluid from the

stomach, and sputa, as well as air, from the bronchial tubes, with a relief that can be gained, in extreme instances, by no other means whatever. I have already referred to the extraordinary manner in which blood is often expectorated from the bronchial tubes, as it were by vomiting. In these instances one or two expulsive actions almost clear the bronchial tubes of the effused blood, rendering it difficult to detect the seat of the hœmoptysis, either by auscultation during life, or by autopsy after death.

Excitement of Respiration by Stimulus to the Afferent Nerves distributed to the Serous Membranes and the various Tissues.

We have seen that if the healthy skin be stimulated a deep inspiration is excited, and that if the skin, when morbidly sensitive, be stimulated, coughing or some other expulsive action may be excited. We have also seen that if the mucous membranes be stimulated an expiratory expulsive action, usually preceded by a deep inspiration, is excited.

Acts of inspiration, expiration, and expulsion, may also be excited by stimulating the afferent nerves of the system.

If any of the nerves of sensation be irritated, so as to give pain, loud cries and deep inspirations are excited.

Vomiting may be excited by extensive injuries to the lower limbs, and by injury or disease of any of the abdominal and pelvic viscera.

When the healthy serous membranes are stimulated, as Haller has shown, no apparent effect is produced; neither sensation nor motion being excited.

If the serous membranes be inflamed, sensory and reflex phenomena are excited. If the pleura be inflamed, cough may be excited. This effect is not, however, invariable, for in many instances of pleuritis, with extensive effusion, cough is quite absent. Cough is most severe, and most frequently present, in those cases in which inflammation affects the pleura lining the diaphragm, and, though less frequently, that lining the intercostal muscles. The cough is, in fact, most frequently present and most distressing in those cases attended with pain. If peritonitis be excited by the effusion into the peritoneum of a foreign irritating substance, such as urine or fœces, vomiting is almost invariably excited.

Influence of the Brain on Respiration.

The brain is not essential to the movements of respiration. Legallois and Flourens found that after the removal of the cerebrum and cerebellum, respiration continues, provided the medulla oblongata be untouched. Although respiration may be performed independently of the brain, yet it is greatly influenced by that organ. We have seen above, from the experiments of Sir Benjamin Brodie and others, the great effect which the brain exercises over respiration, and over the evolution of animal heat, that essential product of respiration.

Chossat removed the brain in a dog. During the first hour (see the Table at p. 186), the respirations were only 11 in the minute; they then gradually increased in rapidity, so that during the third hour they were 101 in the minute; after this they gradually diminished in frequency, sinking to 40 per minute in the sixth hour, and 11 in the seventh. This rate was maintained to the end; the animal survived the operation twelve hours, and during the last hour the respirations were 12 in the minute. During the time that the dog breathed so very quickly, its body cooled with remarkable rapidity, namely 5°6 in the hour. Another dog killed by division of the medulla, and exposed to the air, cooled in the corresponding hour only 4°, and another, similarly served, on which artificial respiration was performed, lost in the corresponding hour only 3°8. Afterwards, when the respiration became slower, the rate of cooling diminished materially, so that, at the eleventh hour, when the respirations were but 13 in a minute, the body had only cooled down 27°5, while the untouched body had lost 29°8, and that on which artificial respiration was performed had parted with 31°3. Dr. Reid removed the cerebrum and broke up the cerebellum in a kitten a day old, and the number of respirations fell from about 100 to 40 in the minute. In another kitten, after the like operation, they fell from 120 to 40. It is to be remarked, as probably bearing some reference to the discrepancy, that while Dr. Reid employed kittens, Chossat operated on a full-grown dog.

We see, from these experiments, that the influence of the brain on the mechanism of ordinary respiration, is by no means so great as the influence of that organ on the essential processes of respiration which go on everywhere in the organism, and which, while they

assist in the removal of the waste, and the renewal of the fresh materials of the frame, at the same time evolve and maintain animal heat. If the influence of the brain be cut off from any particular limb, as it is in paralysis, the respiratory changes do not go on to the same extent in the paralysed as the sound limb; the former limb being colder than the latter, and the circulation in it less vigorous.

As a general rule, having however numerous exceptions, the larger the brain the more active is respiration. This rule is still more marked with regard to the cerebellum, for there is usually a coincidence between the development of the brain, and the development of the respiratory apparatus and functions. It is not that respiration, either in the excitement of its mechanism, or in its essential processes throughout the organism, is so materially regulated by the cerebellum; but that those animals which have a vigorous physical frame, and an active physical life, possess a highly developed cerebellum, on a law laid down with great clearness by Professor Owen and Dr. Carpenter. When the exercise of the animal powers is vigorous, respiration is vigorous.

Influence of Volition on Respiration.

Voluntary respiration, in the strict meaning of the term, is seldom practised; indeed scarcely ever, excepting by the physiologist when observing the respiratory phenomena; or by the patient or other subject of observation, when desired by the medical attendant to breathe deeply, slowly, or quickly.

When a person speaks, sings, or smells, his respiration is in one sense voluntary; that is to say, it is taken as often, and as fully, as the person requires for the exercise of a function which is strictly voluntary. When I will to speak, sing, or smell, I necessarily will to breathe, but my mind is not occupied with the act of breathing, but with the act of speaking, singing, or smelling.

When we perform the infinite modulations of speech and music our respiration is under the most exquisite and varied control of the will.

The influence of the will over speech and music comprehends the highest manifestation of respiration. This is a subject of which I do not here treat. Its successful cultivation by Professor Müller,

Sir John Herschell, Mr. Bishop, Mr. Willis, and many other physiologists and philosophers, enables me to refer with much satisfaction to their monographs on the subject.

Influence of Emotion on Respiration.

Under the influence of violent rage, with a tendency to violent action, the surface becomes instantly excessively red and turgid; the inspirations become quick, full, and energetic, and are performed by the whole associated action of respiration; the nostrils are excessively dilated, the lips are separated, the mouth and fauces are widened, the upper jaw is raised by the action of the muscles depressing the occiput, the lower jaw is depressed, the base of the tongue moves forward and the soft palate is rendered tense; the glottis is excessively widened; the shoulders are raised, the ribs are expanded to the full, and the diaphragm descends to the utmost.

This excited state of the circulation and respiration does not immediately cease on the cessation of rage, but continues for a time, the accelerated condition subsiding gradually; just as we observe that respiration and circulation, once quickened by violent exercise, continue to be accelerated for some time afterwards.

If the rage lead to violent action, the chest is dilated to the full, the breath is held, the glottis being closed, and a powerful and fixed bearing is thus given to all the muscles of the frame, which are exerted with a remarkable and exalted power, under the influence of rage, excitement, or maniacal delirium; so that a feeble frame is endowed for the time with a strength capable of resisting the combined efforts of the strong. Shakspere has thus described this source of power:—

> "Stiffen the sinews, summon up the blood,
> Disguise fair nature with hard-favour'd rage;
> Then lend the eye a terrible aspect;—
> Now set the teeth, and stretch the nostrils wide;
> Hold hard the breath and bend up every spirit
> To its full height!"

During the bursts of deep grief, the face becomes flushed and hot, a peculiar sensation is felt in the fauces and top of the nose, tears gush from the eyes, mucus flows from the nostrils, the mouth is sometimes dried up, sometimes filled with saliva; a deep,

sudden, often sobbing inspiration is taken, with dilated nostrils, severed and retracted lips, and widened mouth and fauces, followed by a vehement, often crying expiration. The succeeding inspirations are quick and deep, and they continue to be so for some time after the subsidence of the paroxysm, gradually resuming and often even falling below their usual quiet standard.

Under the influence of mirth a deep inspiration is excited, the nostrils are much dilated, and the mouth is opened to the widest, the expansion of it being outwards and downwards, under the influence of mirth, while it is outwards and upwards, under the influence of grief; at the same time all the inspiratory muscles are in powerful action. The inspiration is sometimes repeatedly interrupted by the successive closure and opening of the glottis; sometimes it is crowing, owing to the vocalising position of the vocal chords. It is an intercsting fact, that under the influence of rage, grief, and mirth, the glottis, instead of being normally widened during inspiration, in exact proportion to the extent of the muscular inspiratory efforts, is in many instances actually narrowed or even entirely closed. When laughter is hearty, the expiration is exceedingly powerful, and is made in a series of laughing jerks, the breath being suddenly stopped and renewed by the alternate noisy closure and opening of the glottis. In violent laughter, almost all the muscles of the body and limbs are engaged in the successive and alternate actions of inspiration and expiration.

Under the influence of terror, the surface becomes excessively pallid and bloodless; a cold sweat breaks out over the skin. The whole frame, as well as the muscles, are relaxed; the sphincters often give way; the respirations, are often at first short and panting, and then few, feeble, and irregular.

Under the influence of certain depressing mental impressions the surface is of a deadly pallor, the pulse is almost or altogether absent, the respirations are suspended, or fetched at distant and irregular intervals, all the muscles are relaxed, and the person sinks to the ground unconscious. The unconsciousness follows the cessation of the respirations, the cessation of the respirations, succeeds to the universal check to circulation. This syncope may even prove fatal, especially if the body be maintained in a sitting posture.

There is every variety of influence on the circulation and respiration, between the extreme effects of depressing emotion and of rage.

In all these instanees, with the exception perhaps of laughter, the cireulation is first affeeted by the mental emotion and then the respiration. Indeed, whenever the respiratory phenomena are affeeted the eireulatory phenomena must be affected also; circulation being, in one sense, a part of respiration, and respiration a part of cireulation.

Under the exeitement of anger, "scarlet indignation," the surfaee becomes instantly red from the augmented cireulation in the capillaries, and the heart beats with tumultuous power. Under the influence of extreme depressing emotion, the eapillaries of the surface beeome instantly empty and blaneheđ, and a death-like pallor spreads over the eountenance and surface. If syncope do not take plaee, the heart flutters and palpitates irregularly; if it do, the heart's action even ceases, or becomes imperceptible for a time.

The Respiratory and Circulatory Phenomena in Syncope; Cases.

In the following cases, which oecurred among the patients of the Nottingham General Hospital, I observed the phenomena of syneope in espeeial relation to respiration and cireulation.

Hannah Seals, a young woman, aged 18, in delicate health, became faint, pallid, and bedewed with perspiration, on seeing a boy's finger eut. Pulse very feeble, 84. Respirations 40 in the minute; each aet of respiration being very slight. On dashing eold water on her face she drew a very deep inspiration, after which her inspirations (39 in the minute) were much deeper, and the pulse (100) was much stronger than before. She soon revived; and 20 minutes afterwards the respirations were 28 in the minute, the pulse 100.

This person had suffered mueh from gastric pain. The paroxysm was evidently mixed, being partly but mainly due to syncope, and partly to hysteria.

January 9, 1843, Thomas Newton, an athletie, pale-faced man, a frame-work knitter, aged 48. Until very lately he has had very good health. Of late he has been unable to retain his water longer than an hour at a time, and he has had oeeasional dyspnœa.

He eame this morning with fracture of the metacarpal bone of the thumb. When examined, he complained of intolerable pain, and

began to weep; he suddenly became insensible, and sank into a chair, his face being of a death-like pallor, his pulse quite imperceptible. The respirations could not be perceived, and he became more and more ghastly. The chair on which he sat was placed down on its back, so that his head was lower than his feet. His pulse immediately became perceptible (about 90), and he began to struggle convulsively, owing, apparently, to inability to perform an expiration. On dashing cold water on his face he drew a deep inspiration, and continued to breathe 28 times in a minute. On raising his chair, he being still insensible, the pallor returned; the pulse (about 50) was very irregular and intermittent, there being sometimes an interval of 3 or 4 seconds between the beats; the respirations were about 12 in the minute. On dashing cold water on the face, the respirations increased to 28 in the minute, the pulse being about 80, irregular. His intelligence gradually returned.

After half-an-hour, pulse 72, feeble; respirations 14 to 15; his lips were red, his countenance pale.

George Walker, aged 32, suddenly fainted while waiting in the surgery to have a tooth extracted. He was suffering from tooth-ache, and was standing near the fire. He was immediately laid gently on the ground; his face was dark and livid; breathing could not be perceived. The dashing of cold water on the face excited an immediate very deep inspiration. The repeated renewal of the cold dash caused each time a renewed deep inspiration. He soon revived.

October 14, 1842, Ann Oakland, a pale, feeble woman, applied with recent stiffening, from injury of the joints of the ring finger. To restore the power of flexion, the joints were suddenly bent. Severe pain ensued; she breathed quickly, each expiration commencing with a short cry or moan. Pulse feeble, quick. Her surface became very pale; large drops of perspiration exuded over her lips and face. The respirations diminished in frequency, but each expiration still commenced with a faint cry. The respirations were 14 to 16 in a minute. Pulse 36, feeble. Her face became ghastly, her eyes were turned up, her appearance was death-like. She was placed in the recumbent posture; the respirations soon quickened; they were short, little air being drawn in during each inspiration, and each expiration being still interrupted with a cry. At first there were 8 inspirations in 10 seconds, then 3 or 4, and then the

respirations varied. Pulse about 60, feeble. On dashing cold water, and on wafting cool air over her face, she drew deep inspirations. She felt revived; pulse 80 to 100, feeble. A draught of sal volatile was given; the respirations, formerly 20 in the minute, rose to 10 in 15 seconds, each expiration being still accompanied by a cry. The surface now became warmer and less livid. The expiratory interruption shortly ceased; the respirations varied from 20 to 26; the pulse from 70 to 90, feeble. She recovered slowly. Half-an-hour afterwards, when near the fire and warm, the respirations were 16 to 20, irregular, occasionally performed with a deep sigh; the pulse 100.

In the case of a lady affected with hæmoptysis, venesection was decided upon. The lancet was plunged into a vein; it gaped wide open, but not a drop of blood flowed. It was then resolved to open a vein in the opposite arm. She said, "don't you fear me." She took the cup in her own hand, and held out her other arm. The lancet was thrust into the vein, and although, like the other, it gaped wide open, yet no blood flowed. The medical attendant, after gazing for a moment at the gaping orifice, turned his glance on the face of the patient, who seemed to be at that moment expiring, her death being instantaneous.

In this remarkable case, which was related to me by Dr. Boott, the mental emotion arrested the circulation before the loss of consciousness. After a time, however, unconsciousness and death instantly supervened, induced no doubt by the arrest of the circulation through the brain.

Having seen above, at p. 263, the effects of cold and warmth on the circulation, I shall here consider the influence of the brain on the circulation, (a subject already illustrated at p. 194,) and the influence of the circulation in the capillaries on the action of the heart.

The first phenomena observed in Seals were pallor and cold sweat; she was still sensible, but would have fallen unless she had been laid down.

Influenced by the depressing emotion inducing syncope, the circulation instantly ceases in the superficial capillaries, and the blood in them passes onwards, owing to their universal constriction. The retrograde action of the peripheral organs of circulation, the

capillaries, on the central organ of circulation, the heart, is in such cases full of interest. The blood, just before the emotion which caused the syncope, had been sent freely onwards by the heart through the open capillaries; under the influence of the depressing emotion, the capillaries are suddenly closed, so that the blood cannot be sent into them; the heart makes powerful efforts to send the blood forward, but, unequal to the task, it is overwhelmed, and for a time ceases to beat. Dr. Paris relates, that after death from syncope the heart has been found to be distended with blood to an unusual degree. Zimmerman says that "many observations tend to prove that sudden fear has caused syncope, and even death. The face grows pale, the blood seems to stop in the vena cava, or in the right auricle of the heart, the vessels become distended, and the heart itself in these cases has sometimes burst." Philip V. died suddenly, on being told that the Spaniards had been defeated. On opening him his heart was found ruptured. Dr. Stroud, in his work on the "Death of Christ," relates cases in which the heart was ruptured under the influence of intense mental agony.

The influence of obstruction to the circulation through the systemic capillaries on the left ventricle and auricle, is undoubtedly the same with the influence or obstruction through the pulmonic capillaries on the right ventricle and auricle. This influence of the obstruction to circulation through the pulmonic capillaries on the right side of the heart, has been often and well observed. Sir Benjamin Brodie poisoned a dog with tobacco; immediately after respiration had ceased, he opened the thorax. He found the heart extremely distended, and without evident contraction, except at the appendix of the right auricle. In dividing the pericardium, the fibres of the heart were irritated with the point of the scalpel. Immediately both auricles and ventricles began to contract with considerable force, so as to restore the circulation. Dr. John Reid, Dr. Cormack, and Dr. Lonsdale observed, that under the influence of certain narcotic poisons, the pulmonary circulation was obstructed, and the right auricle and ventricle were enormously distended, the heart's action being suspended. In some of these instances, on relieving the distension by opening the jugular vein, the movements of the heart, and the circulation were resumed. In like manner, the influence of the obstructed circulation through the systemic

capillaries, during syncope, causes excessive distension and suspended motion of the left ventricle and auricle.

Under the influence of rage, with a tendency to violent action, the opposite effects to those in syncope are excited on the circulation. The emotion of rage calls immediately into the capillaries an increase in the flow and amount of blood. The surface becomes instantly scarlet; the pulse is bounding, and the heart beats violently. In this case, the capillaries are at first increased in size by the emotion; they are not, however, excessively relaxed. The flow of blood into and through the capillaries, instead of being interrupted or impeded, as in syncope, is rendered more free and rapid. The heart consequently propels the blood onwards with greater facility, and in larger quantity, than it does ordinarily.

The effect of the emotions on the circulation, is transmitted by the nerves, from the brain to the systemic capillaries; in syncope, the capillaries are contracted, in rage they are enlarged. The heart's action, so to speak, is affected in a retrograde manner; being overcome in syncope, by the effective resistance offered to the flow of the blood through the capillaries, and by the consequent excessive distension of the organ; and being increased in power by rage, owing to the increased facility for propelling the blood onwards through the capillaries, and to the increased supply of blood received by the heart.

The subject is illustrated by the difficulty experienced in working a fire-engine when the hose is twisted and the stream obstructed, and, on the other hand, by the ease with which it can be worked when the hose is cut across.

That the brain acts on the heart through the medium of the capillaries, and not on the capillaries through the medium of the heart, is additionally proved by the fact, observed by Dr. Wilson Philip, Sir Charles Hastings, Professor Müller, and others (and which I have myself observed on several occasions), that after the heart is cut out there is for some time a certain oscillatory movement of the blood in the capillaries, both in the web of the frog's foot and in the mesentery of the rabbit. The instantaneous influence of the brain, on the capillary circulation, is well illustrated by an observation of Dr. Thomson, who noticed that when a frog was merely touched the circulation in the web stood still for a moment. That this was owing to the emotion of fear was evident, since, if the touch was repeated again and again, so as no longer to excite emotion,

the circulation was no longer affected. How remarkably does not this sudden action of the brain, through the nerves, on the capillary circulation, contrast with the comparatively feeble and slow influence of cutting out the heart, in arresting the capillary circulation.

Dr. Wilson Philip and Sir Charles Hastings found that on crushing the brain, the capillary circulation and the heart's action ceased instantaneously. Dr. Marshall Hall observed, that on crushing a thigh, the heart's action ceased or became feeble. I conceive that in both these instances the enfeebling or arrest of the heart's action was due to the sudden interruption to the circulation through the capillaries. If the capillary circulation be diminished or arrested by exposure to cold, the same effect in diminishing or arresting the heart's action is induced as when the capillary circulation is interrupted by emotion. In all these instances the effect upon the heart's action is of course retrograde from the capillaries.

The state of the pulse depends more upon the circulation through the capillaries than upon the force exercised by the heart. We can, indeed, accurately anticipate the state of the pulse by the appearance and feel of the limb. If one arm be cold and pallid, the other warm and ruddy, the pulse of the pallid arm will be feeble, of the ruddy arm comparatively strong. This difference in the pulse of each opposite arm is equally observed, whether one arm be cold from external exposure, while the other is warm, owing to external covering; or whether one arm be paralysed, and therefore cold, owing to disease of the brain, while the opposite arm, being healthy, is warm. If the resistance to the circulation through the capillaries be diffused, as in syncope, over the whole body, instead of being confined to one limb, the obstruction in the capillaries will necessarily re-act in a retrograde direction upon the heart, and oppress, retard, or even arrest its action.

The mechanism of the retrograde influence of the circulation in the capillaries on the action of the heart may be readily imitated. If you adapt a large tube to an India-rubber bottle containing water, the slightest pressure will suffice to expel the fluid quickly; but if you adapt only a very fine tube, the most powerful pressure can only force out the fluid slowly and with difficulty. If, while the liquid is coming off slowly in a very fine stream, you continue to force more water through a valvular opening into the bottle, it will necessarily be more and more distended. The left ventricle, in

relation to the capillaries, exactly takes the place of the India-rubber bottle. The blood is forced onwards with difficulty when the capillaries are obstructed, and as the right ventricle acts as a forcing pump, the left ventricle is more and more distended.

This interesting subject is practically illustrated by the following cases, occurring in the Nottingham Hospital :—

October 28, 1842, William Daniell, a smith, aged 51, when standing at work, he suddenly became insensible, and fell forward, with his chin on the anvil. On admission, his face was pale, his surface cold ; he was torpid, but was capable of being roused, and his pupils contracted under the influence of light. The respirations were 20 to 22 in the minute ; the pulse was feeble. He was placed in the horizontal vapor bath. In about five minutes the surface became more warm, the intelligence more active. The respirations 14 in the minute, full ; the pulse 76, much stronger. The mercury in the sphigmometer, applied over the artery, which rose only 2° at each beat when he was admitted, now rose from 6° to 8°. He felt better. He had had no headache, dizziness, or other premonitory sign, and he did not know that he had fallen. Owing to want of work he had been under-fed for about a week. The day before his admission he returned to work, and had his usual allowance of food. In this case the retrograde effect of the improved capillary circulation caused increased power in the heart.

Richard Henson, referred to already at p. 233, was admitted soon after falling from the top of a house. He had rigors, and the surface was very cold. External warmth was applied, when the rigors ceased, and the pulse, previously very feeble, became much stronger, and the respirations, previously 42 in the minute, fell to 14. At a subsequent period the influence of the brain on the pulse and respirations was well shown. Thus, at 20 minutes past 8 p.m., about three-quarters of an hour after admission, his intelligence was imperfect and incoherent, his pulse (66) was very feeble, and his respirations were 8 to 9 in the minute. An hour later, his intellect being then clear, the pulse was 76, much stronger, and the respirations were 16 in the minute.

The reality and rapidity of the action of the brain through the nerves is illustrated by every emotion. As Dr. John Reid remarks, "The effects of shame in producing the sudden suffusion of the face in blushing ; the instantaneous paleness of the face and the

abundant secretion of sweat in terror; the flushing of the forehead in anger; the increased secretion of tears and the diminished secretion of saliva from grief; the effects of the sensation of pain, and of the depressing passions of the mind in diminishing, vitiating, or arresting the secretion of the gastric juice; the increased amount of blood in the erectile tissue of the penis and clitoris, the increased secretion of seminal fluid in the testes, and of an increased quantity of mucus in the vagina, from certain sensations and animal desires; and the increased secretion of milk in the mamma, from the pleasing emotions that arise in the mind of the mother as she looks upon her offspring, all illustrate the effects of the sensation, the mental emotions, and passions, upon the capillary circulation and the secretions." In these instances the influence of the emotion, arising in the brain, causes a local increase in the circulation of the capillaries. This is of necessity independently of the heart's action, since the heart supplies, not only the affected capillaries, but also those of the whole frame.

The exciting emotions, as love, joy, desire, hope, success, all increase the force of the circulation; while the depressing emotions, as fear, dislike, sorrow, indifference, despair, failure, all lessen the force of the circulation. With the increased force of the circulation, muscular power and nervous energy are increased; while, with its diminished force muscular power and nervous energy are diminished. If the circulation be cut off from any cause whatever, whether from the ligature of a great artery (as the aorta, in relation to the lower limbs,) or great loss of blood, or long-continued exposure to intense cold, or the depressing emotions; first the sensory, and then the excitor functions of the nerves are suspended or destroyed, and the muscular power is paralysed. On the other hand, when the circulation is from any cause unusually vigorous, as from the stimulating influence of moderate cold or of exercise, from external stimulants, or from the exciting emotions, the sensory and excitor functions of the nerves are exalted, and the muscular powers are invigorated.

That an influence is transmitted from the brain by the trunks of the nerves to their peripheries, is evidenced by the peculiar thrill or feeling of vibration over the surface excited by various emotions. Suddenly imparted good news causes a thrill of delight. A sudden catastrophe excites a thrill of horror. The stirring eloquence

of an earnest orator, expressed in vibrating tones, excites an universal thrill through the whole assembled audience. Music, with some persons, causes thrill after thrill, varying in extent and situation, to play over the surface.

Dr. Reid truly observes, that in all those cases where sensations and mental emotions act on the capillary circulation and the secretions, "the effects upon the capillary circulation and secretion are produced by an agency sent outwards from the encephalon along the nerves distributed in the structures, whose functions are thus influenced;" but when he states that "the efferent nerves which convey this are not the motor encephalic nerves and the anterior spinal nerves, but the sensiferous encephalic nerves and the sympathetic, and probably also the posterior roots of the spinal nerves," I must express my complete dissent from that profound physiologist. Is it in harmony with the vital laws of nature, that a nerve shall simultaneously, or even consecutively, transmit impressions from the centre to the surface, and likewise from the surface to the centre? that the nerve of sensation, an afferent nerve, shall also be an efferent nerve, transmitting impressions from the nervous centres to the surface? No, the sensiferous encephalic nerves and the posterior roots of the spinal nerves can scarcely be both afferent and efferent nerves. Dr. Reid brings forward neither proof nor argument in favour of such a supposition, and, failing these, his view must necessarily fall to the ground. Neither can we consider, as being at all more tenable, his supposition, that the influence from the nervous centres is transmitted through the sympathetic. There can be no doubt that the sympathetic nerves transmit the influence of the separate ganglionic centres on vascularity and secretion; but that they should transmit a like influence from the great nervous centres cannot be regarded as possible, since the connection between those centres and the sympathetic are comparatively scanty, while their connections with the various sympathetic ganglia are numerous and universal.

That great physiologist, Sir Charles Bell, has thus accurately stated what nerves convey the influence of the brain over the vascularity of the surface:—

"When the anatomist shall find both the portio dura of the seventh and the fifth going to the integuments of the head and face, he may naturally ask, why are there two nerves to the surface? and he

will probably reflect, that although the principal office of the nerves of the skin is to convey impression to the sensorium, yet the influence of the mind is conveyed to the surface. The condition of the mind in passion, for example, is as forcibly communicated to the skin as to the muscles themselves; and, therefore, if a branch of the fifth be necessary to convey sensation from the surface to the sensorium, the seventh is necessary to the change of vascular action, and to the condition of the pores when affected by a cause proceeding from within outwards."

I consider that the motor or efferent nerves are undoubtedly the nerves which transmit the influence exercised by the nervous centres on the capillary circulation and the secretions; and not the sensory or afferent nerves.

We find, then, that during emotions, an influence is transmitted by the efferent nerves from the brain to the extremities of the cutaneous nerves; that sensations are thus excited at the surface, and that the capillary circulation is there affected, being increased by exciting, and diminished by depressing emotions.

We have already seen that excitement of the surface stimulates the extremities of the incident nerves, and excites a deep inspiration; and that the continuance of the source of excitement in the increase for a time of the superficial circulation, as, for instance, when a sinapism has been applied, excites, through the medium of the incident nerves, an increase in the number and extent of the respiratory movements, lasting for some time; as long, indeed, generally, as the stimulated condition of the surface exists.

Under the influence of the various exciting and depressing emotions just illustrated, the increase or diminution of the respirations I conceive to be owing to the increased or diminished vitality and excitement of the incident nerves, caused by the retarded or accelerated circulation in the capillaries. The first effect perceived is the influence on the circulation in the capillaries, then that on the respiration. In every instance, when the circulation is roused, the incident nerves are stimulated, and the respirations, by a reflex action, are quickened and deepened. On the other hand, whenever the circulation is depressed, the incident nerves are deprived of their stimulus, and the respirations are diminished either in volume or frequency, or both. In both instances mental emotion acts

through the medium of the efferent nerves on the state of the circulation, which, in its turn, excites or depresses the afferent nerves, and through them induces the condition of the respiration.

The respiratory movements excited by emotion are involuntary; more than that, they are performed altogether in spite of the will: volition cannot control them. It appears, indeed, that in proportion as the voluntary control of the brain over the excito-motor functions is withdrawn, those functions become more active and powerful. Emotion is, in fact, in contradistinction to, and in contention with, the will. The higher the development of reason, of regulated will, the lower is the influence of emotion. In the child, the reason is undeveloped, but emotion is supreme; in the educated man, the educated will is supreme, and the results of emotion are repressed. Throughout life, those who have exquisite sensation, an excitable temperament, a proneness to be actuated by emotion, have but little control over their passions, being subjected to the caprice of desire, not to the discipline of reason. On the other hand, those who have the most highly developed and disciplined mind, are in the least degree under the influence of desire and emotion.

During emotion, there are two physiological influences especially at work, the increased excitement of the incident nerves; and the lessened control of the mind over the excito-motor functions.

Those emotional affections, hysteria, laryngismus stridulus, chorea, and some varieties of stammering, are morbid illustrations of the interesting subject now under consideration. In all of these affections, the control of the mind over the excito-motor functions is lessened, while the excito-motor functions themselves are exalted. In considering those affections, I for the present, put out of sight any centric influence which the medulla oblongata and spinal marrow may exert.

The Respiratory and Circulatory Phenomena of Hysteria. Cases.

The subjects of hysteria have exalted sensibility and great susceptibility to emotion; their minds are feebly disciplined, and their emotions readily overwhelm the control of the brain over the reflex movements.

In the following selected cases, the fits of hysteria were closely observed, with especial reference to the respiratory and circulatory phenomena :—

Matilda Marriot, aged 20, a somewhat pale young person, of full features, and of delicate skin, was an in-patient of the Nottingham Hospital, affected with spinal curvature and amenorrhœa. She complained much of headache, which gradually increased in severity. Her face was flushed, and had been so all the morning; her eyes were heavy, and she looked sleepy.

Two or three minutes after sitting up in bed, her face being more flushed than before, she suddenly began to breathe with difficulty, and made a loud noise both during inspiration and expiration. She sometimes breathed very rapidly and irregularly, as often as ten or twelve times in ten seconds; sometimes she drew a very deep inspiration. After a time she made eight or nine inspiratory efforts in succession, about ten in five seconds, so as conjointly to make one inspiration, followed by a deep expiration. Most of the respiratory acts were attended by a vocal noise. On applying the stethoscope over the larynx, a loud, sharp, shrill, piercing noise was heard during each inspiration, and a graver sound during each expiration. The inspiratory vocal noise was loudest at the beginning of the act. Pulse feeble, 120. On lifting the eyelid and bringing the finger near to the eye, the lids did not close; on touching the lashes they did; consciousness was therefore absent, while the reflex functions were active. The face was somewhat flushed. When cold water was dashed on the face, she corrugated the eyelids, opened the mouth, drew back the head, and fetched a deep breath. After this she breathed deeply several times, but soon relapsed, again taking short, quick, noisy inspirations. Sometimes she drew a peculiar, deep inspiration, composed of eight or ten noisy arrested efforts, at the end of each of which the glottis was closed by the contact of the vocal chords. On again dashing cold water on the surface, the same effects were produced, followed again by a relapse. After eight or ten repetitions of the dashing, she became sensible. She complained of headache. Pulse 100, stronger. She still sobbed occasionally. She readily relapsed; when the renewal of the dashing again caused deep, powerful, and repeated inspirations, which were soon however replaced by sobbing. She then gradually became sensible; but she still occasionally sobbed during inspiration, and shivered during expiration.

February 20, 1842.—Ann Palmer, aged 50, an out-patient of the Nottingham Hospital, suffering from inflammation of the finger. She had been liable to fits for some years.

While I was removing a portion of nail from a patient, she went into an hysterical fit. Her breathing was quick and laborious; her eyelids were shut; she was speechless and powerless, but she could still hear. When in the fit, standing, the pulse was 190. She nearly dropped to the ground. When placed in a chair, the pulse was 120. She was still in the fit, speechless, and apparently insensible. On wafting cold air repeatedly and forcibly over her face, she came to herself, and spoke. The pulse was then 90; in a minute it was 80; and in four or five minutes, 63. The first fit came on 20 years previously, owing to a fright.

February 27, 1842.—Sarah Marshall. Has just been in a fit, insensible. When it came on, she felt as if she would choke. She now breathes with considerable noise, 70 times in a minute. About four or five times in a minute she performs the actions of deglutition. Pulse 84. She complains of great epigastric pain.

March 4.—Immediately after being blamed for not taking her medicine, she began to weep, she breathed quickly, and fell down in a fit. While in the fit, inspiration was impossible, owing to closure of the glottis. After this, she made twelve or fourteen altogether ineffectual efforts to inspire. She dilated the nostrils, and the lips protruded and retracted in rapid succession; the respiratory muscles of the neck were firmly, and then, gently contracted in rapid alternation. The abdomen protruded and returned in a series of rapid movements, synchronous with those of the cervical muscles. The thoracic parietes remained stationary. These vain attempts at inspiration were repeated during from five to ten or fifteen seconds, and were succeeded by five or six quick, not very full inspirations. Subsequently, the respirations were occasionally convulsive, sometimes the inspiration, sometimes the expiration, being interrupted at the beginning by the closure of the glottis. During the whole time she was quite insensible. At length, suddenly, after being in the fit about twenty minutes, she took five or six very deep forcible inspirations, became quite sensible, and asked for water. She breathed very quickly for about twenty minutes after coming out of the fit.

October 24, 1842, Maria Feeley, an out-patient, while waiting to

be seen, suddenly began to cry. The respirations were about 20 in the minute. The inspirations were deep and drawn quickly; the expiration was sometimes crying throughout; sometimes it consisted in a series of noisy interruptions, owing to repeated closure of the glottis. The mouth was distorted, being opened wider during inspiration than expiration, the cheeks being at the same time drawn upwards, and the eyelids corrugated. Sometimes the respirations were noiseless. In a few minutes the convulsive crying gave place to convulsive laughter, when each respiratory act consisted in a rapid, deep inspiration, with widening of the mouth, the angles being drawn downwards, the cheeks being no longer elevated, and the eyelids no longer corrugated; this was followed by an expiration, consisting of several forcible successive expiratory acts, each being suddenly checked by noisy closure of the glottis. The fits of laughter were alternated by ordinary respirations, as well as by respirations in which, while she took a very deep inspiration, six or eight silent pauses were made. Sometimes all the muscles of inspiration were put into action, but silent closure of the glottis prevented the ingress of air. During the fit the pulse was 125; afterwards, the respirations being 24 in the minute, the pulse was 110. After recovering from the fit, she said, that last night the drollery of a companion had excited uncontrollable laughter. This was followed by intense headache. The thought of the events of the previous evening brought on the present fit.

February 15, 1842.—Elizabeth Hopkinson, aged 19, is now insensible. Her inspiration begins with a feeble, sharp, cooing sound, and is suddenly checked by closure of the glottis, owing to the contact of the vocal chords. During the time that inspiration is thus prevented, the scaleni act strongly, and the abdomen is considerably protruded. The expirations are not vocal but purring in character. The respirations (60 in the minute) are accompanied by permanent convulsive muscular contraction of the arms. On exposing the surface to the air, the respirations gradually became normal.

The characteristic respiratory phenomena in the fit of hysteria would appear to be the frequent approximation of the vocal chords during, in many instances, inspiration as well as expiration, so as to excite either temporary closure of the glottis, with general struggling, during the vain attempt to respire; or stridulous or sobbing inspiration, and crying or laughing expiration. It is to be

remarked, that this approximation of the vocal chords is to be observed during most of the emotions and the emotional diseases, when the excito-motor functions are abnormally exalted. This is instanced in the cries of rage, the sob and cry of grief, the crowing inspiration and noisy interrupted expiration of laughter, the interrupted and stridulous inspiration and the crying expiration of laryngismus stridulus, the interrupted, struggling, convulsive expiration of epilepsy, and the noisy, interrupted, and struggling inspiration and expiration of hysteria.

It appears then, that when the vocal chords, which are usually so obedient as the exquisite instruments of speech and music, are under the influence of emotions and of the emotional diseases, they are then the involuntary and irrepressible agents in general convulsion. They may come into silent contact with struggling attempts at respiration; or they may come into noisy, vocal approximation, so as to induce sobbing or crowing during inspiration, and crying or laughter during expiration.

It is evident that the respiration may be accelerated and disordered in hysteria quite irrespective of sensation, since the more aggravated forms of hysterical fit existed in Marriott, Marshall, and Hopkinson, although they were quite unconscious, and for a time incapable of being roused. It is certain, then, that in these cases the remarkable and exalted respiratory movements were not consensual, that is to say, they were not called into play by an influence excited in the afferent nerves by sensation, transmitted to the seat of consciousness in the brain, and thence reflected back through the spinal marrow and the afferent nerves, so as to excite the respiratory muscles. In these cases, the reflex movements of respiration must have been excited, not through the sensory, but through the excitor functions of the afferent nerves.

While the fit of hysteria usually comes on when the subject of it is conscious, the cases just alluded to show, that under the influence of the paroxysm the patient may speedily become unconscious. This state of unconsciousness may be induced either by the greatly increased pressure of the blood upon the brain, caused by the violent expiratory efforts; or possibly by the greatly diminished pressure of the blood upon the brain, caused by the unusual inspiratory efforts.

The cases just recited show that when the paroxysm is severe,

owing to the closure or narrowing of the glottis, dashing cold water upon the surface excites deep inspirations, with free opening of the glottis. Consciousness is not usually restored by the first dash; but after it has been effectively renewed time after time, so as to excite repeated deep inspirations, intelligence is at length awakened, apparently under the influence of the circulation of a more stimulating arterial blood through the brain, and of the restored balance of pressure exerted by the blood upon the brain.

In hysteria the fit is evidently occasioned by the emotion, and prolonged by the state of unconsciousness. Both of these influences, in fact, by withdrawing the control of the brain from over the direct, or centric, and reflex, or eccentric spinal functions, give to those functions undue predominence. I shall again have occasion to refer to this important point. The repression of the emotion, and the restoration of consciousness, accompanied in either instance by the cessation of the fit, are alike promoted by dashing cold water on the surface, or by any other stimulant that may excite healthy deep inspirations.

Respiratory Phenomena in Laryngismus Stridulus. Case.

In laryingismus stridulus some source of irritation is usually present, morbidly exciting the reflex functions, such as painful dentition, a deranged state of the mucous membranes, or deficient exposure of the surface to the atmosphere out of doors. The fits may be excited by emotion; or they may come on during sleep; in both of which instances the control of the brain being withdrawn, the increased reflex functions become predominant.

I had a recent opportunity of observing the respiratory phenomena in laryngismus in the following case:—

George Newsom, aged seven months, a small shrivelled baby, fed by hand for six months. A fortnight previously the child was affected with cattarrh, and on the following day he had frequent paroxysms of laryngismus stridulus. These attacks occur chiefly when asleep, sometimes about twenty times in the night; they also come on when he coughs, cries, or takes food, and, though less frequently, when he is frightened or fretted. "The quieter he is kept, the more it seems to check the fits." He is evidently less subject to the paroxysms when freely exposed to the air. Strong convulsive fits frequently follow the attacks of laryngismus.

The child had two slight attacks when sitting at my side. During the fit the inspiratory efforts were violent and struggling, but silent; the mouth was wide open, but the air was denied ingress by the closure of the glottis. The surface became livid, the tongue of a dark purple. Blowing on the face and sprinkling it with cold water evidently excited increasing separation of the vocal chords, the inspirations becoming at first stridulous, and finally easy, noiseless, and hurried, 68 in the minute. "Opening the window," the nurse says, "by letting the cold air blow upon the face, seems to bring him to better than anything." The first fit came on when I was feeling the gums; the child cried, and closure of the glottis speedily ensued. The paroxysm, which lasted about two minutes, was cut short by blowing upon the face. The second attack came on when the child was asleep.

A third fit, less severe than either of the former, came on, and gradually went off without any apparent exciting cause. The closure of the glottis was not absolute, but there was stridulous, almost interrupted inspiration. The lips pouted forward all round, forming a tense, prolonged, funnel-shaped, oval orifice; the tongue was rigidly convex from side to side; the nose became quite flat on the face, owing to the excessive dilatation and retraction of the nostrils. The limbs, both the legs and arms, were in continual motion, all the muscles being rigid. The stridulous inspiration soon gave place to crying expiration. The glottis now expanded freely, all the other extreme inspiratory movements still continuing. There were thirteen respirations during the next ten seconds after the crying had ceased. He soon became tranquil, his respirations being less frequent, about forty in the minute. Shortly afterwards he fell into a doze, the eyes being half open and the respirations irregular, and often interrupted by a short pause.

For additional cases I refer to the valuable writings of Dr. Marshall Hall, Dr. Ley, Dr. West, Mr. Roberton, and others. The last-named gentleman has detailed many cases in which the free exposure of children, subject to this disease, to the country air, proved of essential service in checking the paroxysms and putting an end to the disease.

In these cases the renewed attacks will frequently be warded off by removing the source of peripheral irritation, as by incising the gums, emptying the bowels of their offensive contents, or improving

the quality of the food; by avoiding emotional influences; and by rousing the child if its sleep be too profound. Perhaps of all remedies nothing proves so permanently efficient as the free exposure of the surface to a dry bracing air, a plan which usually restores the healthy balance of the reflex functions.

Chorea is an emotional disease, in which the reflex functions are morbidly excited. Respiration is affected in chorea, but not to a degree entitling me to consider further the nature of the disease. In three cases of chorea recently observed by me in St. George's Hospital, the abdominal muscles were permanently tense. In one of these, Dr. Bence Jones pointed out to me the peculiar action of respiration; the abdominal walls retracted during each inspiration, the diaphragm was inactive, and the inspiration was entirely thoracic. This kind of respiration was not present in the two other cases just referred to. The movements of respiration partake somewhat of the jerking irregular character of the other movements, as was well marked in an interesting case described by Dr. Walshe.

Dr. Todd thus illustrates the emotional character of chorea:—"So frequently do mental causes give rise to chorea that Rufz, in investigating eighteen cases, traced the origin of eleven of them to fright. In chorea the nervous system is obviously peculiarly excitable. Choreic patients are much more agitated in the presence of others than if left to themselves. Of this we have abundant evidence in hospital practice. When the physician approaches the bed of a patient with chorea, accompanied by a crowd of students, the movements become greatly augmented, and continue so until the cause of excitement has been removed."

Effects on the Respiratory Movements of the immediate withdrawal of Cerebral Control over the Reflex Functions.

I have traced, to a certain extent, the influence of the brain over respiration, first through volition, and then through emotion.

While will controls and suppresses the reflex functions, emotion suppresses the influence of the will and excites the reflex functions.

I purpose to consider here the effect on the respiratory movements, of the complete and immediate withdrawal of the control of the brain over the reflex functions.

The effect of the control of the brain over the reflex spinal functions has been ably illustrated by Professor Volkman, Mr. Barlow, Dr. Budd, Dr. Carpenter, and Dr. Marshall Hall. I beg to refer to their respective memoirs, and especially to Mr. Barlow's valuable Essay.

If the spinal marrow of the frog be divided in the lumbar region and one fore limb be irritated, that fore limb only is moved; but if one hind limb be irritated, both hind limbs are thrown into convulsive movements. Reflex movements are not excited in the opposite fore limb, owing to the superior control of the brain; while convulsive reflex movements are excited in both hind limbs, owing to the withdrawal of the cerebral control. The same stimulus that will excite reflex movements when the control of the brain is inactive, will not excite them when it is active.

During sleep the control of the brain over the reflex movements, though not annihilated, is lessened. Mr. Barlow touched the palm of a sleeping child: his finger was grasped by the infant's hand. When the child was awake, no such movement was excited.

In hemiplegia and in paraplegia, if the paralysed limb be irritated, convulsive reflex movements are excited in the paralysed limbs, although no such movements are excited in the limbs which are under the control of the will.

If the reflex spinal movements are morbidly excitable, as in hydrophobia and tetanus, and in those under the influence of strychnia, then the cerebral are unable to restrain the reflex functions, and the slightest stimulus excites violent convulsive reflex movements. In these cases, even in hydrophobia, the convulsive reflex movements may be restrained for a time by a powerful effort of the will. This was instanced in the case of that disease related by Dr. Marcet. When water was sprinkled on his face unawares, violent convulsions were excited; but when he was prepared for it, convulsions were not so excited, the reflex spinal being held in check by the cerebral functions.

While all other reflex movements are usually kept in check by the superior control of the brain, the ordinary automatic respiratory movements are performed with constant regularity, both when awake and when asleep. These automatic respiratory movements may be restrained for a time, but for a time only, by the will. If

cold water be dashed suddenly over the whole surface, an uncontrollable deep inspiration is taken. If the water be dashed on the face unawares, a deep inspiration is excited; but when the person is prepared for it, the will exerts its superior control, and the inspiration is restrained. If a person walk into the sea, he can at first restrain the respiratory movements; but when he has gone beyond a certain depth, when, in fact, the reflex functions are unusually excited over a greater extent of surface, he can no longer restrain the deep inspiratory movements, which are often interrupted by sobbing.

We have already seen that, under the influence of volition, the reflex movements, even those of ordinary respiration, may be arrested. On the other hand, under the influence of excited emotion, the control of the brain is withdrawn, while the reflex functions are unduly stimulated, owing to the increase in the capillary circulation; and deep, often convulsive, respiratory movements are excited.

We have also observed that, under the extreme influence of the depressing emotions, not only are the cerebral functions depressed and annihilated, but the reflex spinal functions are also depressed, or even annihilated, by the partial or total suppression of the capillary circulation; and the reflex respiratory movements are for a time almost or even altogether arrested.

The child, just after its birth, is altogether the creature of the reflex functions; through their agency it breathes, takes its food, expels the fæces and urine, and moves the body in an agitated lively manner. Consciousness is wanting. The educated man almost completely subordinates the reflex spinal to the cerebral functions, since, with the exception of ordinary respiration, all those offices are performed by volition.

Convulsions caused by sudden Comatose Unconsciousness.

When comatose unconsciousness, or unconsciousness from which the person cannot be roused, is rapidly induced, the direct and reflex spinal functions being at the same time either unaffected or exalted, then expiratory convulsions are excited. The control of the brain over the reflex, and, as will be shown hereafter, over the direct spinal functions, being suddenly withdrawn, those functions are unduly excited, and more or less violent convulsions ensue.

By whatever means the complete and sudden unconsciousness is produced, provided the reflex functions be unaffected, convulsions are equally induced. Dr. Burrows tied a ligature round the neck of a rabbit; another he bled to death; each animal died violently convulsed. The brain of the former animal was surcharged with blood; of the latter, almost devoid of blood. In the former the loss of consciousness was owing to the unduly increased pressure of the blood upon the brain; in the latter, to the unduly diminished pressure of the blood upon the brain. In neither of these instances was the spinal reflex function affected; in both of them the control of the brain over those functions was suddenly removed, and in both of them violent reflex convulsions were induced.

In syncope, from mental emotion, comatose unconsciousness is produced with a rapidity equal to its production in the cases just instanced, yet no convulsions ensue; for while in those cases the reflex functions are either unaffected or exalted; in syncope the reflex functions are, as we have seen above, annihilated simultaneously with or even before the production of unconsciousness.

That the convulsions are not owing to any immediate central action of the brain itself, is proved by the physiological fact that the brain may be punctured or cut in every direction, and that the cerebral and cerebellar hemispheres may be removed in progressive slices, or at once, provided the medulla oblongata be untouched, without the production of convulsions. When an animal is pithed or beheaded, no convulsions are excited. The absence of convulsions in these instances is owing to the shock which, acting on the whole nervous system, destroys or suspends for a time the reflex functions. That the reflex functions are thus suspended for a time, has been conclusively proved by Dr. Marshall Hall. In fact, as in syncope, so when the animal is beheaded, the cerebral and the reflex spinal functions are simultaneously annihilated, and all movements, whether direct or reflex, are suspended.

The effect is quite different if, after beheading the animal, the circulation through the capillaries be maintained by means of artificial respiration. Sir Benjamin Brodie decapitated a dog, and then kept up artificial respiration; the body of the animal, which was previously at rest, was moved in a very remarkable manner by constant and powerful contractions of the muscles of the trunk and extremities. In another dog whose head was

removed, Sir Benjamin kept up artificial respiration, and then injected into the stomach nine ounces of infusion of tobacco. At the time of the injection the body of the animal lay perfectly quiet and motionless on the table. Ten minutes afterwards the voluntary muscles in every part of the body were thrown into repeated and violent spasmodic action. The joints of the extremities were alternately bent and extended; the muscles of the spine, abdomen, and tail, alternately relaxed and contracted, so as to turn the whole animal from one side to the other. In the former of these experiments, the body of the animal at first lay still after being decapitated, since, although the control of the brain was removed, the reflex functions were suspended, owing to the shock and the deficient circulation. When, however, owing to the artificial respiration, the arterial blood circulated in the capillaries, and stimulated the excitor functions of the peripheral nerves, spasmodic reflex movements were induced, those movements being no longer held in check by the control of the brain. When the blood was rendered more stimulating by tobacco, the reflex functions were still more stimulated, and the extraordinary alternate movements described above were excited.

Respiratory and Circulatory Phenomena in the Epileptic Convulsion. Case.

The epileptic convulsion is the type of the class of convulsions which attend sudden comatose unconsciousness.

In the following case I observed the respiratory phenomena of the epileptic convulsion.

February 24, 1842. William Brooks, aged 16. Is in an epileptic fit. He takes two or three deep inspirations, followed by strong expirations; after the second or third inspiration, the vocal chords come in contact, so as to close the glottis, and prevent the performance of expiration; universal convulsions immediately ensue, so violent that four men can scarcely restrain him from injuring himself. All the expiratory muscles are powerfully exerted in the vain endeavour to force asunder the vocal chords, so as to perform expiration. The muscles of the jaws, the limbs, and the back are in violent action. This struggling, violent attempt at expiration lasts for from three to ten seconds, during which time the fearful convulsions continue, the face flushes and becomes

swollen, and the pulse is about 180, sometimes very feeble, or even almost imperceptible.

The violent convulsive attempts at expiration above described were renewed at frequent intervals during about fifteen minutes, at the end of which time the respirations were performed freely and uninterruptedly (32 in the minute), and all the muscles became relaxed. Immediately after the fit the pulse beat 36 times during the next ten seconds, or at the rate of 216 in the minute. At the end of the minute they had fallen to 25 in ten seconds, or at the rate of 150, and in about ten minutes the respirations were 17 to 18, and the pulse 100 to 130 in the minute. He still remained unconscious. In about half-an-hour, when still unconscious, he smiled during each inspiration, and laughed during each expiration. Shortly afterwards he said, "I'll not be served so." On tickling him, he renewed the laughter, reflexed all the limbs, and said, "Don't do that." At this time he was manifestly unconscious, for on approaching the finger to the open eyes, the eyelids did not contract, but they closed on touching the eyelashes. After this he occasionally sighed deeply, and in a few minutes became conscious; he had no recollection of any dream; he was listless and languid; his respirations were 15, his pulse 104, in the minute.

February 25. Is again in a fit. He makes two or three rapid respirations, which are interrupted by closure of the glottis and violent convulsive attempts at expiration; all the limbs are violently convulsed, the head is thrown forcibly backwards, and all the expiratory muscles are in powerful action; the whole neck and face are turgid with venous blood, the thyroid body being greatly enlarged; the sterno-cleido, the platysma myoides, and the fasciæ of the neck, are contracted and tense, apparently just before the renewal of the closure of the glottis and the convulsive attempts at expiration. He gathers himself up for the fit by contracting the pectoral muscles, the muscles of the arm and shoulder, and the fascial muscles of the neck.

February 26; half-past eight, p.m. Has suffered much from pain in the back, which came on during the last fit. The pain is opposite the last dorsal vertebra. He is now in the progress of a fit. Just before he became insensible, he complained of his back, and desired that he might be held. He lay insensible for some minutes, respiring freely, the muscles being relaxed. He was

stripped, and the surface was exposed freely to the air; a convulsive effort at expiration was made, followed by free inspiration. Pressure over the last dorsal vertebra excited a convulsion. The seat of pain was fomented, and friction was employed to the surface. The fits are not nearly so violent as on the previous occasion; their violence appears to have been staid by exposure to the cold air, the cold dash, and frictions. After making many deep inspirations, he emerged from the state of insensibility.

This case shows the dependence of the epileptic convulsions on the arrested expiration, owing, as Dr. Marshall Hall has shown, to the closure of the glottis. The control of the brain over the direct and reflex spinal functions being withdrawn, those functions became predominant and excessive. During the third attack, as in the cases of syncope and hysteria given above, the reiterated stimulus to the surface excited, reflexly, deep inspirations; those inspirations restored the balance of pressure of the blood upon the brain, and stimulated that organ by the circulation through it of oxigenated blood. These effects, acting as causes, restored consciousness, renewed the cerebral control over the spinal functions, and put an end to the paroxysm.

The cause of the unconsciousness in many cases of epilepsy is by no means apparent; but it may be owing to disease of the cranium (Dr. Abercrombie relates three such cases); or to disease of the brain (Dr. Abercrombie relates seven such cases); or to various causes producing congestion, and consequent increased pressure of blood upon the brain; or to various causes producing diminished pressure of blood upon the brain; or to various causes poisoning the blood, the poisoned blood circulating through the brain; or to exciting or depressing emotions.

In all these instances; comatose unconsciousness may be induced while the reflex functions are unaffected, or are even unduly excited, as by the circulation of poisoned blood.

In some cases affection of the direct and reflex spinal functions acts as the primary cause of the convulsions; then epilepsy may be occasioned by disease of the spinal marrow (Dr. Abercrombie relates four such cases); or by irritation in the stomach and intestines; or by uterine irritation.

In the latter cases some secondary and additional cause must be at work to produce unconsciousness.

The epileptic fit frequently comes on after a hearty meal, causing great and flatulent distention of the stomach; in such cases, besides the influence transmitted from the stomach by the par vagum to the nervous centres, there is an increased difficulty to the return of blood from the brain to the heart, owing to the pushing up of the diaphragm and consequent compression of the thoracic organs, as well as the pressure excited by the stomach upon the liver, the blood contained in which is thus unduly thrown upon the heart.

Dr. Marshall Hall, in a recent important paper, has attributed the unconsciousness to the prevention of the return of the blood from the brain, caused by the irregular contraction of the platysma myoides.

The epileptic fits frequently come on during profound sleep, the sleep in such cases passing into sopor, the sopor into epileptic coma.

Puerperal convulsions are of the same general character with epileptic convulsions. Certain differences in the pathology of those diseases have been recently pointed out by Dr. Tyler Smith.

Of 200 cases of puerperal convulsions collected by Dr. Murphy, 46 occurred before labour, 90 during labour, 25 after labour; in 39 cases no precise information could be obtained.

Dr. Murphy attributes the convulsions to excess of blood, loss of blood, and impure blood.

The immediate exciting cause of the unconsciousness and convulsions, may be,—increased pressure of the blood upon the brain; diminished pressure of the blood upon the brain; and the circulation of poisoned blood (urea) through the brain and the system.

Comatose Convulsions induced by Narcotic Poisons.

Certain of the narcotic poisons may produce convulsions with unconsciousness; of these the œnanthe crocata may be said to be the type. In ten cases of poisoning by that plant, related by Mr. Bossey, the men fell without warning, insensible and in convulsions.

Belladonna, hyoscyamus, and stramonium produce delirium, followed by coma; convulsions sometimes accompany the coma, sometimes the delirium.

Ether, chloroform, and alcohol, at first exhilerate the cerebral functions, then they produce sopor, and afterwards coma. We have already seen that these poisons, as well as the class of which belladonna is a type, at first stimulate, and then exhaust, the reflex functions, through the medium of the excited capillary circulation. Dr. Snow and myself have both observed that when ether and chloroform are administered so as rapidly to produce unconsciousness, muscular rigidity and sometimes even convulsive movements may be induced; but if administered slowly, rigidity and convulsions are not induced.

Opium seldom excites convulsions in man. I have, however, met with 23 cases, scattered through the British journals, in which convulsions were produced by opium. In the lower animals convulsions are always excited by opium, but these convulsions are not epileptiform, but like those produced by strychnine. The lower the animal in the scale, the more frequent are convulsions, the reflex spinal functions being less under the control of the brain in the lower grades. This is in keeping with the fact that convulsions more frequently affect the child than the adult. Thus, of twenty recorded cases in which children were poisoned by opium, ten had convulsions.

This fact is in harmony with the results of an analysis which I made of 150 cases of cerebral disease recorded by Dr. Abercrombie; of these—

78 had convulsions, of whom . . .	39 were above the age of 12.	
	39 were below the age of 12.	
72 had no convulsions, of whom . .	64 were above the age of 12.	
	8 were below the age of 12.	
In adults, the proportion of cases in which there were convulsions to those in which there were no convulsions, was		39 to 54.
In children, the proportion was		39 to 8.

If the wourali poison be injected into the veins, struggling convulsions with unconsciousness are very speedily induced; but if the wourali be inserted into a wound, the action of the poison is slow, and either no convulsions, or very slight convulsions, are induced. In such instances I believe this to be the explanation;—when the poison is injected into the veins, the brain is rapidly deprived of consciousness, while the reflex functions are stimulated, rather than depressed; and as the control of the brain over the reflex functions is withdrawn, reflex convulsions follow. If, however, the poison act

slowly, the cerebral and the reflex functions are depressed and destroyed simultaneously, and no convulsions ensue.

In like manner prussic acid, coneine, and poisons of a like class, excite or do not excite convulsions with unconsciousness, in proportion as the poison acts rapidly or slowly on the system.

In like manner also convulsions with unconsciousness are sometimes excited when the blood is poisoned with urea, owing to its non-elimination through the kidneys.

If asphyxia take place rapidly, violent convulsions with unconsciousness invariably ensue; but if asphyxia be brought about slowly, convulsions seldom ensue. In the one case the reflex functions are excited, the control of the brain being withdrawn, while in the other case the reflex are destroyed simultaneously with the cerebral functions.

Convulsions are much more frequent in cases of acute than of chronic cerebral disease.

Thus, from an analysis of the cases related by Dr. Abercrombie, I find that—

Of 31 cases in which the brain was *acutely* inflamed . . { 25 had convulsions; 6 had no convulsions.

Of 29 cases in which the affection of the brain was chronic, as from tubercular disease (12 cases) and abscess (17 cases) { 14 had convulsions; 15 had no convulsions.

Of 23 cases of apoplexy with extravasation . . . . . { 7 had convulsions; 16 had no convulsions.

We have seen that when the control exercised by the brain over the other nervous forces is suddenly withdrawn, then the direct and reflex spinal functions, previously held in check, are suddenly let loose, and violent convulsions ensue. If, however, the direct and reflex spinal functions are suspended, simultaneously with the control of the brain, then no convulsions ensue.

Influence of the Medulla Oblongata and Spinalis (Myelon) on the Movements of Respiration.

If the brain be removed, respiration still goes on; if the tuber annulare be cut away until within a few lines of the medulla, the facial and buccal respiratory movements cease, owing to the destruction of the reflex arc formed, through the nervous centre, by the fifth and seventh pairs, as incident and motor nerves. On extending the incisions to the origin of the eighth pair, respiration ceases.

If the spinal marrow be divided in successive slices from below upwards, the movement of rib after rib is destroyed. If it be cut

across at the lower cervical vertebræ, all the intercostal muscles are paralysed; but the first and second ribs are still raised by the scaleni, and the clavicles, scapulæ, and sternum, by their proper muscles. The diaphragm continues to descend during inspiration.

If the spinal marrow be divided at the third cervical vertebra, the scaleni and the diaphragm cease to act; but the sterno cleido and trapezius, and the muscles of the face and neck, are still in action.

If the spinal marrow be divided above the origin of the par vagum, respiration ceases, but gasping of the mouth still continues for a time.

The facts of pathology are in keeping with the experimental facts of physiology.

If the brain be absent in the fœtus, the medulla and tuber annulare being entire, as in the case detailed by Mr. Lawrence, respiration is still performed.

If the tuber annulare be destroyed by injury, extravasation of blood, or disease, the facial and palatal respiratory movements cease, and the breathing becomes stertorous.

If the medulla oblongata be destroyed by injury or disease, respiration ceases.

Destructive injury or disease of the spinal marrow arrests the movements of all those respiratory muscles which are supplied with nerves from below the seat of the injury or disease.

The depressing effects of the narcotic poisons, such as chloroform, produce, through their action upon the centres and peripheries of the nervous system, the same progressive suspension of the various respiratory movements. During the administration of chloroform, the powers of the lower nervous arcs are first suspended, the lower limbs becoming powerless; then certain of the respiratory movements give way, costal respiration ceasing, while diaphragmatic respiration still continues. Under the depressing influence of chloroform, the functions of the nervous system are not only suspended from below upwards, they are suspended also from above downwards, the facial and palatal respiratory movements being arrested, while the diaphragmatic movements continue. It is not the nervous centres only that are affected by the action of chloroform; the nervous peripheries are affected also in a corresponding manner, by the diffused circulation of the poisoned blood. With

regard to the suspension of the respiratory movements of the face, those movements are probably arrested in great part by the local action of the inhaled chloroform.

In many dying persons, the nervous system dies gradually from below upwards; first motion and sensation cease in the lower limbs; then the respiratory movements of the ribs are arrested; then those of the diaphragm; the nostrils still dilate for a time, but when they do so no longer, the mouth continues to gasp widely, at longer increasing intervals; finally, a few retractile movements play around the angles of the mouth.

Flourens, after removing the brain, divided the spinal chord just below the last cervical vertebra, and costal respiration ceased. He irritated the cut surface of the lower section of the divided spinal marrow, and inspiratory movements of the ribs were excited. He divided the spinal marrow above the third cervical vertebra, and the diaphragm ceased to act: he then irritated the cut surface of the cord, and so excited a diaphragmatic and costal respiration. He altogether arrested respiration by dividing the medulla at the origin of the eighth pair: he then irritated the spinal marrow, and a complete respiratory movement was excited.

We observe, then, that if we cut across the spinal marrow at any part, the movements of those respiratory muscles, which are supplied with nerves below that part, are arrested; but an extraordinary act of respiration can still be excited by stimulating the spinal marrow itself.

On the direct or centric action of the Spinal Marrow, and its influence on Respiration.

I request your close attention to some important points in the physiology of the spinal marrow. I allude to the mode in which movements are excited, on the one hand, directly, by stimulating the spinal marrow itself; and, on the other, reflexly, by stimulating the incident nerves.

Dr. Marshall Hall pinched the toe of a brainless frog, and immediate universal reflex movements followed: although he continued to pinch the toe, relaxation of all the muscles speedily ensued. If he ceased to pinch the toe he could, after a short pause, re-excite the same reflex movements by a repetition of the same stimulus.

From the researches of E. H. Weber and of Volkmann, as detailed by Mr. Paget, it appears that when the incident nerves are continuously stimulated by a magneto-electric current, alternate reflex contraction and relaxation of the muscles ensue. When the stimulus is withdrawn, the movements instantly cease.

It is not so with the direct or central spinal functions. If the spinal marrow itself be continuously excited by the magneto-electric current, fixed muscular contraction is excited, and this fixed contraction continues for a time, even after the withdrawal of the stimulus.

How different are these direct or centric movements from the reflex or eccentric movements; while the latter are intermittent, the former are continuous; while the latter are speedily exhausted and as speedily re-excitable, the former are only exhausted when the life of the nervous system is itself destroyed.

These points, illustrated so well by physiological experiments, are still more instructively illustrated by disease. In meningitis of the spinal cord, as in meningitis of the brain, the central organ is in general permanently stimulated. It will be seen, from the following analysis, which I have made of the cases of spinal disease recorded by Dr. Abercrombie, that of eight cases of spinal meningitis, six were affected with permanent muscular rigidity. In those cases the continued stimulus applied to the nervous centre excited continued muscular contraction; neither the excitability of the nervous centre nor the contractility of the muscles were exhausted.

	HAD					
	Muscular rigidity.	*Muscular rigidity, with tetanic spasms also.*	*Ordinary convulsions.*	*Epileptic convulsions.*	*Paralysis without convulsions.*	*Neither paralysis nor convulsions*
In 8 cases of spinal meningitis	6	5	1	0	0	1
In 4 cases of inflammatory vascularity of the chord	0	0	2	1	1	0
In 19 cases of ramollissement of the chord	5	3	5	0	9	0
In 21 cases of chronic disease of the chord, tubercles, &c.	3	0	11	3	4	0

From this table we see that of 8 cases of spinal meningitis, 6, or 2-3rds, had muscular rigidity; while of 44 of diseasc of the

cord itself, only 8, or less than 1-5th had muscular rigidity. In the former cases the direct spinal functions were usually exalted, the cord being permanently stimulated; in the latter they were usually depressed, the cord being injured.

It may be laid down, then, as a definite law, that while the reflex or eccentric spinal functions are *intermittent,* the direct or centric spinal functions are *continuous.* Volition, or the cerebral command over the muscular movement is *temporary*; it is neither so rapidly exhausted as the reflex functions, nor yet so continuous as the direct spinal functions. While reflex movements, excited by stimulating the surface, can only last for one or two seconds; direct movements excited by a continued stimulation of the spinal marrow, are permanent; while direct movements, excited by the will, can usually only last about five minutes. It is manifest that the excitability of the incident nerves and the control of the brain are exhausted in these instances, and not the contractility of the muscles, since under the direct influence of the exalted spinal marrow the contractility of the muscles is enduring.

The reflex spinal excitability may be represented thus - - - - - - - - - - - -
The voluntary excitability thus ..... ——— ——— ———
And the direct spinal excitability thus ..... ———————————

In this interesting and instructive fact, that the reflex spinal functions are intermittent, while the direct spinal functions are continuous, we have a key to the nature and cause of certain physiological and pathological motor phenomena.

I have already addressed myself to the reflex motor phenomena, and I shall now enquire what muscular movements, in health and disease, are caused by the direct action of the spinal marrow, or, in other words, what movements are continuous?

The action of all the sphincters is continuous, and for that reason I infer that the action of all the sphincters is excited directly by the spinal marrow. Thus the sphincter of the anus, the urethra, and the uterus, the cardiac and pyloric orifices of the stomach, and the œsophagus, are ordinarily always in a state of contraction. That action is only interrupted by a higher or more energetic power; thus, by volition the anal and urethral sphincters can be opened; they can be opened also by strong reflex excitation. By reflex excitation, the cardiac and pyloric orifices of the stomach, and the os uteri can be opened.

A series of sphincters are continuously closed or contracted only during sleep, such as the eyelids, the iris, and often the mouth. Open the eyelid of a sleeping person, and the pupil will be seen small and contracted; immediately he awakes, the iris springs backwards, and the pupil dilates.

The eyelid is continuously influenced by the spinal cord, but when we are awake, the brain exercises a higher control than the cord, and the eyelids are open; they cannot, however, be kept open by the exercise of the will beyond a certain time; and an instantaneous rest is every now and then given to volition by their irresistable and momentary closure. The quiet unperceived winking of the eyelids, owing, as I conceive, to the direct action of the spinal marrow, exerting its continuous force and making itself manifest whenever the cerebral action flags; is very different from the forcible reflex closure of the eyelids, caused by touching the lashes, so beautifully illustrated in Dr. Marshall Hall's experiment on the horse, just felled by the knacker.

In fact, the direct influence of the spinal marrow never flags; its power, though feebly exercised, is enduring. It is allied to, nay, it is identical with tonicity. The diffused firmness of all healthy muscle is indeed owing to the direct influence of the spinal marrow. Cut off the connection between the cord and the muscles, and their tonicity is replaced by flaccidity.

The reflex action, though it can only last for a second or two, is yet exercised with superior force, and overcomes, by a short, powerful effort, the direct spinal action. It is not, for instance, that the sphincter ani relaxes when the contents of the rectum are expelled, but that the levator ani, excited reflexly, overcomes the sphincter, though still in action.

We have already seen that the brain controls the reflex spinal functions; we shall see that in like manner the brain may control the direct or central spinal functions. In the waking state the control of the brain is predominant, and the direct spinal functions are for the most part in abeyance, with the exception, in fact, of the contraction of some of the sphincters. When persons are about to fall asleep, are fatigued, or are affected with paralysis, a slow stretching of all the limbs is frequently effected, along with a deep, slow, wide-mouthed inspiration or yawn. The slow and continuous muscular action concerned in stretching the limbs is owing, I conceive,

to the centric action of the spinal marrow. The brain gradually goes to sleep, and ceases to control the central spinal functions; at first those functions are performed with unusual vigour, just as the reflex functions are performed with unusual vigour when the cerebral control is suddenly withdrawn. When sleep is complete, the more exalted centric spinal actions are in abeyance, and the sphincters are alone in action. When a person is suddenly awakened, the same yawning and stretching process is repeated.

When chloroform is administered, especially if it be given quickly, as consciousness disappears, universal muscular rigidity and stretching of the limbs come on. Hence, while the cerebral control is diminished and withdrawn, the centric functions of the spinal marrow, stimulated by the chloroform circulating through it, excite universal muscular rigidity. If the chloroform be persevered in, the centric functions of the spinal marrow are gradually destroyed from below upwards, and the sphincters, as well as the muscles of the frame, relax.

Tetanus presents us at the same time with the type of those convulsions with consciousness, which are excited by a morbidly exalted reflex function; and of that universal continuous muscular rigidity which is caused by the exalted centric excitation of the spinal marrow. The tetanoid convulsions are united with tetanoid muscular rigidity. Owing to this rigidity, the abdominal muscles of expiration are in constant action, and each inspiration is to a certain extent resisted by the action of those muscles.

In persons affected with hydrophobia, and in those under the influence of strychnia, convulsions with consciousness are present; but there is frequently no permanent muscular rigidity. In such cases I consider that there is morbid exaltation, not of the centric, but of the eccentric action of the spinal system.

In some cases of hysteria, there is permanent cataleptic rigidity of the muscles, which is manifestly caused by the exalted centric excitability of the spinal marrow.

In chorea, the muscles of the abdomen are often permanently rigid, owing I conceive to the morbid state of the spinal marrow.

In a case of albuminuria, detailed by Dr. Semple, the patient was affected with unconsciousness; and with rigidity, now of one set of muscles, and then of another. The occurrence of the rigidity indicated that the spinal marrow was being stimulated by

some morbid influence. The temporary, local, and migrating character of the rigidity, indicated, as the *post-mortem* examination proved, that the rigidity was not due to spinal meningitis, or spinal disease, but to the more general and varying influence of poisoned blood circulating through the nervous centres.

In the violent convulsive movements of hysteria, and of epilepsy, asphyxia, and all convulsions with unconsciousness, in the performance of which the vocal chords come together, and the whole muscles of the frame are violently rigid, it appears to me that the closure of the vocal chords, and the muscular rigidity, are owing, in part at least, to a centric morbid excitation of the spinal marrow.

The same may, I conceive, be said of crying and laughter, of sobbing and crowing inspiration, and indeed of all those semi-convulsive emotional movements in which the vocal chords come irresistibly together. In these instances I conceive that, while the control of the brain over the nervous system is lessened or suspended, the centric or direct, and the eccentric or reflex spinal functions are, as in tetanus, simultaneously exalted.

On the Causes which excite Ordinary Respiration.

I have hitherto attempted to explain only those extraordinary acts of respiration which are excited reflexly by stimulating the peripheries of the nerves, either at the surface, or in the internal organs; those respiratory acts which are caused by volition, emotion, or comatose unconsciousness; and those which are produced by immediately stimulating the spinal marrow.

In most of those instances, the causes exciting the extraordinary act of respiration is palpable.

It is by no means so easy to discover the physiological causes of ordinary respiration. Inspiration and expiration follow each other with noiseless regularity. We are not conscious that we breathe. The exciting cause of ordinary respiration is not palpable. This is however to be noticed, that respiration and bodily exertion are in exact relation to each other.

In order to estimate, with some approach to exactness, the amount of air respired when at rest and during exertion, I constructed an apparatus, by means of a valved ori-nasal inhaler, and a balloon, made of gold beater's skin, to receive the expired air. The balloon held about 600 cubic inches. My breathing capacity

is about 300 cubic inches; and I exactly filled the balloon by blowing into it as much air as I could during two of the deepest possible expirations.

						Cubic inches.
When I sat,	I respired about 16 times in the min.;	I filled the balloon in about 90 secs.,	by from 24 to 26 expirations,	the volume of each expirtn. being abt	24	
When I walked abt 4 miles in the hour,	22	„	„ 30 „	„ 10 to 11	„	60
When I ran at a moderate speed,	30 to 34	„	„ 12 to 18	„ 6 to 9	„	66 to 100
After running as fast as possible, I stood still almost out of breath. I filled and emptied the balloon seven times in succession;	During the 1st inflation	„	6 secs.,	„ 5		120
	„ 2nd „	„	12 to 14	„ 8		75
	„ 3rd „	„	16 to 20	„ 10		60
	„ 4th „	„	25 to 30	„ 13 to 14		44
	„ 5th „	„	40 secs.,	„ 15		40
	„ 6th „	„	45 „	„ 18		33
	„ 7th „	„	50 „	„ 20		30
Immediately after running up hill, at the top of my speed, when out of breath,	I filled the balloon by			3		200
When running very fast, on level ground,	„			4		150

We thus see that I respired the same quantity of air during six seconds immediately after running, that I respired during ninety seconds, when sitting still; in other words, I inspired sixteen times more air when almost out of breath than when at rest.

Every muscular exertion causes increased decay in the muscular structure; that increased decay involves increased oxygenation, augmented respiration, and more rapid circulation. We know that if a muscle or any other organ be exercised, the circulation of blood through that organ is immediately increased. More oxygen is conveyed to the exercised part; its oxygenation and decomposition are consequently effected at the same time that there is, in the increased supply of blood, an increased supply of the materials of nutrition. It is not alone in the muscles that the blood circulates more rapidly and abundantly during exertion, the whole circulation being increased through the cutaneous and pulmonary capillaries.

When the flow of blood through the cutaneous, muscular, and pulmonary capillaries is increased, it is evident that the cutaneous, muscular, and pulmonary incident or excitor nerves will be unusually stimulated.

When the surface is stimulated by the dashing of cold or hot water, or by the application of an external irritant, we have already seen, at p. 205 and elsewhere, that successive deep inspirations are excited; and that, at the same time, there is increased circulation, with redness of the surface. The increased respiratory movements are excited reflexly by the increased stimulus to the incident or excitor nerves, afforded, I conceive, by the immediately augmented capillary circulation, as well as by the immediate external stimulant.

In like manner, when the muscles are vigorously exercised, the incident nerves of the muscles are immediately stimulated by the muscular movements; and the incident nerves, both of the surface, the muscles, and the lungs, are unusually stimulated by the increased capillary circulation. The cutaneous, muscular, and pulmonary incident nerves being thus stimulated, chiefly, I conceive, by the augmented circulation, increased reflex respiratory movements are excited. The extent to which the increased respiratory movements are excited is proportioned to the increased capillary circulation.

That the increased movements of respiration during muscular exertion are excited not alone by the muscular movements, but by the augmented circulation also, is evident, since, the increased inspiratory movements continue for some time, even after the muscular exertion is arrested. It is clear that the quiescent, perhaps exhausted muscle, can no longer excite the still increased respiration. We find, however, that the circulation is still increased in force, amount, and rapidity; and so long as the circulation is so increased, the respiratory movements continue to be increased likewise. In exact proportion as the augmented capillary circulation gradually regains its ordinary level, so do the increased respiratory movements gradually resume their ordinary play.

In the illustration just given of increased respiration, with increased circulation from exercise; just as in the illustrations previously given of increased respiration, with increased circulation from the application of external stimulants; it is evident, I conceive, that the increased respiratory movements have been excited reflexly through the stimulation of the incident nerves by the augmented capillary circulation.

From the table given above, it appears that when I walk at an ordinary quick pace I respire three times as much, and when I run I respire sixteen times as much, as when I sit still. The cause of the increased respiration when I walk is manifestly the same with the cause of the still more increased respiration when I run.

It is evident that there is no difference in the essential nature of respiration, whether we sit, walk, or run; the only difference is in degree. Sitting, walking, and running, are ordinary healthy acts of life, and the respiration may then be classed as ordinary respiration, whether performed to a moderate, an increased, or an

excessive extent. I consider that the cause of respiration resides in each of these instances, in the stimulus which the blood circulating through the capillaries affords to the adjoining peripheries of the incident nerves; and that the ordinary acts of respiration are caused reflexly by the excitement of the afferent nerves by the circulation.

That the ordinary movements of respiration are reflex, is demonstrated by the researches of Dr. Marshall Hall, Dr. John Reid, and other physiologists. The experiments of M. Volkman, referred to at p. 313, shew that when an electro-magnetic current is passed downwards through the cord, continuous movements are excited, which last even after the withdrawal of the electro-magnetism. If, on the other hand, the electro-magnetic current be transmitted upwards along the afferent nerves, a series of reflex muscular movements take place alternately with muscular relaxation. The *intermittent* movements are reflex, while the *continuous* movements are direct or centric in their origin.

Now intermittent muscular contractions, alternating rhythmically with intermittent muscular relaxation, are characteristic of, and essential to the respiratory movements. Consequently, the movements of respiration are reflex movements, and have the source of their excitation in the incident nerves.

Taking it then for granted that the ordinary tranquil movements of respiration are reflex, the important question that we have now to answer is this; How are the movements of inspiration excited?

According to Professor Müller, it is the theory of M. Kind, that it is the stimulus of the air, acting on the cutaneous nerves, and transmitted to the spinal cord, which gives rise to respiration as a reflected movement.

That the air frequently does act as a stimulus on the cutaneous nerves, so as to give rise to reflected movements of inspiration, is amply proved in many instances already cited. In a case recorded by Dr. Marshall Hall, a new-born child did not breathe at first, but as soon as the bed-clothes were lifted up, and the surface was exposed to the air, it breathed freely.

In Ann Oakland (p. 286), affected with syncope, wafting cold air over the face excited deep inspirations. When Elizabeth Hopkinson (p. 297) was in an hysterical fit, the surface was exposed to the air, and the hysterical was gradually replaced by normal

respiration. In George Newsom (p. 299), when respiration was interrupted or stridulous during the paroxysms of laryngismus stridulus, the exposure of the surface to cold air excited normal inspirations.

Sir Humphry Davy immersed a rabbit in hydrogen until it was apparently inanimate; he then restored it to the air, and in less than a minute it inspired. On another occasion he placed a water lizard in nitrous oxide; in 15 minutes it lay as if dead; after being exposed to the atmosphere for three or four minutes, it took an inspiration (p. 210.) Dr. Goodwin put a toad into water after exposing its heart and lungs; in 40 minutes its heart had ceased to beat, and it gave no sign of life. It was now removed into the air, and before the end of two minutes it took a quantity of fresh air into the lung (p. 211.) Dr. Edwards took a frog, and having cut out its heart, he immersed the animal in water until it appeared lifeless; he exposed it to air, and it immediately began to recover (p. 212). Professor Müller kept a frog in hydrogen for four hours, when it was apparently dead; but it revived when restored to the air. Dr. Hall divided the spinal marrow of a frog, and immersed it in water; there was no respiration; on being exposed to the free open air, respiration was gradually restored. In some cases of poisoning by opium, the depressed respiratory powers have been roused by free exposure to a stream of cold air (p. 228).

The air, especially when it plays in a fresh, cold stream on the surface, has a vivifying effect on the cutaneous incident nerves, exciting through them increased reflex inspiratory movements; and I may here state that it has a like vivifying effect on the circulation in the cutaneous capillaries.

We see, then, that the stimulus of air, especially if in a cold stream, may re-excite, maintain, and accelerate respiration when it has been recently suspended from various causes.

While it is certain that air, especially when it plays in a current, is one of the most important stimulants of inspiration, through the medium of the cutaneous nerves, especially of the fifth pair, we may safely infer that air is not the only such stimulant. Indeed, external warmth, the dashing of cold or warm water on the face, the application of ammonia to the nostrils, and of external stimulants to the surface, as we have already seen, act as excitors of inspiration with even more intensity and vigor than the exposure to

a current of air. We have also seen that the increased vigor of the cutaneous circulation excites increased respiratory movements.

External warmth is one of the most important means of restoring respiration when suspended, and of maintaining and accelerating it afterwards.

It is especially in the cold-blooded animals, and in the hybernating mammalia, that external warmth excites respiration. In those animals the respiration is accelerated in exact proportion to the increase, and retarded in exact proportion to the diminution of the external temperature, until, at a temperature at and somewhat above 32°, respiration ceases.

This is illustrated, as we have already seen, in an interesting and conclusive manner by Spallanzani, in snails (p. 237); by Mr. Newport and Mr. Barlow, in insects (p. 238); by Spallanzani and by myself, in fishes (p. 242); by Dr. Edwards, in frogs (p. 246); by M. Saissy, Dr. M. Hall, and M. Regnault, in the hybernating mammalia (p. 248); and by Dr. Edwards, in the imperfect young of certain mammalia, and the prematurely born of all (p. 250). In all of these instances, of each of which I would urge your re-perusal, the respirations almost or altogether ceased at or about the freezing point, and increased gradually in number and volume as the temperature gradually increased.

It has been shown above, that this is not so with the higher adult warm-blooded animals, their respiration, within certain limits, being quickened by a lower, and rendered slower by a higher temperature (p. 252). If, however, they are exposed to a temperature above 100°, MM. Delaroche and Berger have shown that the respirations are much accelerated (261). The hot bath, as Mr. Barlow has observed (p. 261), quickens and deepens respiration. Dr. Miller, in his work on "Madeira," relates that "a man entered one of the *estufas* at a temperature of 160°, the air being saturated with water and spirituous vapour from wine. Pulmonary exhalation was suppressed, and, after remaining three minutes and a half, perspiration by transudation was excited to such an extent that sweat streamed from every part of his body. The respiration was increased in frequency, and he appeared so exhausted as to be scarcely able to stand. He continued panting for eight or ten minutes after he came in contact with the external atmosphere, which at the time was from 65° to 70°."

We thus see that in the perfect and healthy mammalia, in man himself, respiration is quickened so as to be even rendered panting by the exposure of the surface to a temperature above 100°.

If the temperature of adult warm-blooded animals be much lowered by long-continued exposure to extreme cold, or by inanition, as in Chossat's experiments (p. 257), the respirations become slower and slower when the animal becomes torpid and is at the point of death. If at this critical point, when the respirations have actually ceased, the animal be exposed to an elevated temperature, in two minutes the respirations become marked, and in six minutes they are quite re-established.

The re-establishment of the respiratory movements by external warmth, after they have been arrested by external cold, is admirably illustrated by Mr. Barlow in the experiment in which he decapitated an eel; after a time the gaspings ceased, but they were renewed with vigor when the head was plunged into water at a temperature of 90° (p. 260.)

This is further illustrated in Dr. M. Hall's remarks, at p. 289, and in the cases of poisoning by opium, related by Dr. Alison and Mr. Walne, in which, after repeated cold dashing, the surface became cold, the respirations slow; but on their applying external warmth, the surface became warm, and the respirations were accelerated (p. 226).

While in Mr. Barlow's experiment the gaspings were re-excited by heat, independently of the circulation; it is to be observed that in all those instances in which the animal is not mutilated, the restoration of respiration is coincident with or even consecutive to the restoration and acceleration of the superficial capillary circulation. Indeed, in the cold-blooded animals, and in the hybernating mammalia, the circulation continues sluggish, although the respiration is suspended.

The influence in exciting quickened and deepened respiration by dashing cold water on the surface is related at pp. 205, 208, 226, 228, 285, 295; of ammonia to the nostrils, at p. 226; of external irritants, at p. 230; and of electro-magnetism, at pp. 230, 231.

In all of these instances, the respirations were excited and accelerated in a reflex manner by the stimulation of the incident nerves of the surface.

Cold has a remarkable effect on respiration.

In the cold-blooded animals, and in the hybernating mammalia, in proportion as the temperature is lowered, respiration is depressed, until at and above the freezing point breathing is arrested (pp. 237, 251).

It is quite otherwise with the higher warm-blooded animals; in proportion as their temperature is lowered, respiration is quickened. If, however, the cold be intense and long-continued torpor comes on and respiration is lowered, and at length arrested. Cold in the higher classes excites respiration, so long as the nervous energies are are high; but as soon as they are blunted, cold depresses and extinguishes respiration, in fact, they are then reduced to the condition of cold-blooded animals (pp. 251, 263.)

The various external influences, of which I have just spoken, evidently excite respiration under peculiar circumstances; it may be truly said that they excite or influence ordinary respiration. But when we consider that the movements of respiration are performed for a longer or shorter time under water, and in certain gases, as well as in air, and during extreme heat and extreme cold, it is manifest that the agencies in question do not in themselves habitually excite ordinary respiration.

We have also seen that the ordinary respirations are not excited by the direct influence of the central organs, either the brain or the spinal marrow.

The ordinary respirations are reflex movements, and are necessarily excited by the stimulation of incident nerves.

Those reflex movements, though they can be regulated, cannot be habitually excited by any irregular external influence. Any such influence, after it has stimulated, would necessarily exhaust the excitability of the incident nerves, and so, after exciting, would arrest respiration, unless it were replaced by some stimulus of an opposite character.

The reflex movements of ordinary respiration must then be excited by some stimulus that pervades the whole system; that, after it has stimulated the incident nerves, and so excited respiration, can reinforce their excitability, and then again rhythmically re-stimulate the incident nerves, and so re-excite respiration. They must be excited by a stimulus from within the organism, that varies in force in proportion to the higher or lower energies of the system; and to the varying external stimulants that excite or

influence respiration. Such a stimulus resides in the circulation, and in the circulation alone.

The circulation of blood is necessary to the excitability both of the incident and the motor nerves. Tie the aorta, and sensation, excitation, and motion, are cut off from the hind limbs; remove the ligature, and with the returning circulation, there is returning sensation, excitation, and motion. More than this, the nervous energies rise with the energy of the circulation, and the nervous energies flag when the circulation flags.

When respiration is increased by external stimulants (p. 206 and seq.), by exercise (p. 317), or by mental emotions (p. 280 and seq.), the circulation is in each instance excited in exact proportion to the excitation of respiration; and after the cause exciting respiration and the circulation has ceased, the accelerated respirations continue as long as the circulation is energetic; as soon as the circulation regains its ordinary level, the respirations resume their ordinary play.

When respiration is depressed or arrested by depressing external agents (p. 237 and seq., p. 258), by exhaustion, by inanition (258), by food, by stimulants, or narcotics circulating in the blood (p. 214 and seq.), or by depressing emotions with syncope (p. 284 and seq.), the circulation is in each instance depressed or arrested in exact accordance with the depression or arrest of respiration.

Professor Volkmann considers that the respiratory movements, reflex in their nature, are excited by the carbonic acid circulating in the blood, throughout the entire organism, acting as a stimulus on all the incident nerves, and by no means exclusively on the vagus.

Now, while blood when charged with carbonic acid and accumulated in the capillaries, acts as a most powerful stimulant to the incident nerves, and excites, as I shall show hereafter, those violent convulsive inspiratory movements which take place during asphyxia, it can be conclusively shown that the presence of carbonic acid in the blood diffused throughout the organism, does not excite ordinary tranquil respiration.

I would here engage your best attention, while I trace the circulation of the blood through the system during ordinary respiration; and its influence in exciting inspiration.

Since the expiration immediately precedes the inspiration, it is quite clear that the physiological cause exciting the inspiration must exist during, or just at the end of, the act of expiration. I

remarked the other day, when Dr. Snow was administering chloroform to a patient, that the dilatation of the nostril commenced during the act of expiration. Inspiration begins at the nostrils, and may be excited even during costal and diaphragmatic expiration.

The blood sent over the system by the left ventricle is arterial, and contains less carbonic acid than the venous blood received into the lungs.

The experiments of Poisseuille have shewn that during the act of expiration, arterial blood is propelled with greater *force* and in greater *quantity* through the whole system, than during the act of inspiration.

The increased force and quantity with which the arterial blood circulates through the systemic capillaries during, and especially towards the end of each expiration, act so as to give an increased stimulus to the incident systemic nerves, especially the cutaneous nerves. I say, especially to the cutaneous nerves, not because those nerves are the special excitors of inspiration, but because the great proportion of the incident nerves, possessing both sensory and excitor functions, are distributed to the skin; the whole of which is exposed to the constant play of external agents. The face is more richly endowed with incident nerves than any other part; and both the ordinary and extraordinary respiratory movements have one of their chief seats of excitation in the face. I consider that the increased stimulus so applied to the systemic incident nerves, during excitation, excites through the spinal marrow the reflex movement of inspiration.

It is during expiration that the systemic circulation is most energetic; that the systemic incident nerves are thus stimulated, and that the next inspiration is excited. During inspiration, the excitability of the incident nerves of the system is exhausted. During expiration, the excitability of the incident nerves, exhausted during the previous inspiration, is first restored, and then the nerves are stimulated by the increased energy of the circulation.

There is during expiration and inspiration an *alternation* of increased and of exhausted excitability of the incident nerves, with an alternation of contraction and relaxation of the muscles of inspiration.

It is clear, then, that it is not blood charged with carbonic acid, but, on the contrary, blood charged with oxygen, that is distributed

with greater force and volume, during expiration, to the systemic capillaries, so as to excite reflexly the next inspiration. Professor Volkmann is, therefore, manifestly in error when he attributes the cause of inspiration to the carbonic acid contained in the blood diffused throughout the organism; since the quantity of oxygenated in proportion to carbonized blood circulating in the capillaries is greatest during expiration, when the cause exciting the next inspiration is in operation.

Having shown (I believe on sufficient grounds) that the movements of inspiration are chiefly excited through the incident nerves of the skin, stimulated through the cutaneous capillaries:—I have now to enquire whether the respirations are also excited through the incident nerves of the lungs, stimulated by the circulation through the pulmonary capillaries?

Before considering the influence of the pulmonary branches of the par vagum on respiration, I here insert Dr. Snow's narrative of the experiment already detailed at page 219.

"Dr. Sibson came to perform some experiments on the functions of the pneumogastric nerves. Mr. Marshall was present the greater part of the time. A youngish dog, weighing twelve pounds, was placed in a 3,000 cubic inch jar, into which one drachm and a half of chloroform was put. The dog became gradually insensible, without offering any resistance or exhibiting any excitement; his respiratory movements, which were 20 in a minute before the chloroform was put in, were not materially quickened. At the end of five minutes he was taken out quite passive and relaxed. In the first incision through the skin of the neck, a considerable vein was divided, which caused the loss of an ounce or two of blood before it could be tied. After this, as the dog was recovering from the effects of the chloroform, ether was given to it by means of the small inhaler applied to its nose. The pneumogastric nerves were dissected out to a small extent, and a thread passed under each of them. The breathing was much quickened whilst the dog was inhaling the ether, and the quickness of breathing continued for a minute or two after the inhalation was left off, showing that it did not depend on the presence of the vapour in the air cells. The trachea was divided, and on irritating the interior of the trachea with a probe, the breathing was quickened a very little. On the probe being passed down, however, to the bifurcation of the trachea,

efforts at coughing were excited. On passing the probe up into the larynx, struggles were caused, apparently the result of pain or uneasiness, for the effects of the ether had been allowed to subside before the probe was introduced into the trachea.

"The dog was again made insensible with ether, by applying it first on a sponge to the opening in the trachea, then by introducing into the trachea a brass tube attached to the balloon holding 900 cubic inches, which had been filled up with air after one drachm and a half of ether had been put in. The respirations were rendered exceedingly rapid and forcible at this time. The probe being passed up into the larynx when the dog was insensible, no struggles were occasioned, but the breathing was rendered a little quicker and deeper. On pinching either pneumogastric nerve, the same effect was produced, *i.e.*, the breathing was rendered a little quicker and deeper. On dividing the right pneumogastric nerve, the respirations at once fell to six in the minute, and became deep and full. There was a short pause after each inspiration, and a long pause after each expiration. The division of the left pneumogastric nerve made no further difference (it had been previously pinched).

"Various observations were made on the larynx and pharynx after the pneumogastric nerves were divided; and subsequently ether was administered by a sponge applied to the opening in the windpipe. It gradually quickened the respirations from one in ten seconds to one in nine, eight, and ultimately seven seconds. Preparatory to trying to arrest the action of the heart with chloroform, some time after these observations with ether, chloroform was given on a sponge applied to the opening in the windpipe, in order to make the dog insensible, and thus keep him quiet during the final experiment. It was found that the chloroform in a very little time began to make the respirations quicker, they being first rendered apparently as natural as before the division of the pneumogastric nerves, and then becoming very deep and forcible, 90 in the minute.

"At one part of the experiment, and after the pneumogastrics were divided, Dr. Sibson introduced a stop-cock into the trachea, which, being of narrow calibre, increased the length and force of the inspirations and expirations, and the stop-cock being half turned, so as still further to lessen the aperture, the inspirations were rendered still longer; and I particularly remarked that the

stop-cock being half turned at the end of an expiration, and before the commencement of the next inspiration, that inspiration immediately occurring was rendered of twice the length of the previous one, or, at all events, was much longer and more forcible.

"The dog having been made totally insensible by chloroform given on a sponge, the usual chloroform inhaler was adapted to the trachea by means of a piece of elastic tube, six or eight inches long, into which a smaller tube was put at the end next the trachea, wide enough to allow of easy respiration. The dog thus breathed to and fro through the inhaler, the water bath of which was at 120°. Two drachms of chloroform were immediately put into the hitherto empty inhaler, and after drawing five or six deep and sonorous inspirations, the breathing ceased; the sounds of the heart, however, continued for a little time (half a minute to a minute) afterwards, and after they could no longer be heard, the dog drew one or two deep and final inspirations.

"On the body being opened, immediately afterwards, the right auricle was found to be contracting feebly, and the right ventricle just perceptibly. The muscles contracted strongly under electro-magnetism. On the following day the heart was opened, the cavities of both sides were found about half full of blood, which was coagulated, but not very firmly."

This experiment coincides with the experiments of Legallois, Dr. John Reid, Longet, Volkmann, and of many other physiologists, demonstrating that while the par vagum exercises a very important influence on respiration, yet that the integrity of that important nerve is not necessary to respiration.

M. Volkmann removed the lungs from a new-born animal, yet the movements of respiration were performed rhythmically for the space of 40 minutes. This fact is in keeping with the experiment in which Legallois removed the heart of a new-born rabbit, and yet the creature gasped repeatedly and rhythmically for the space of twenty minutes. It is evident that here the inspirations were not excited by the circulation through the pulmonary capillaries.

The experiment detailed at page 219, and that in the appendix, show, that although ether and chloroform remarkably accelerate respirations, yet the respirations are not materially quickened at first when the vapour enters the lungs and the blood circulating in the

pulmonary capillaries; they are not indeed accelerated until the stimulus is conveyed by the circulation over the systemic capillaries. More than this, respiration is remarkably quickened by the administration of chloroform, and slightly by that of ether, even after the division of the pneumogastrics; when, in short, the reflex influence could not be excited through the pulmonary incident nerves, their connexion with the spinal marrow being cut across.

Although it is quite established that the division of the pneumogastrics causes a remarkable diminution in the number of respirations, yet it does not diminish their force. On the contrary, the power with which the inspirations are performed is greatly increased after the division of the par vagum. In the experiment just related, immediately before the division of those nerves, the animal breathed quietly, the mouth and nostrils being quiescent; immediately after their division, the mouth and fauces, and nostrils, were expanded to the utmost during each inspiration; a great number of additional inspiratory muscles were called into play, and the causes exciting inspiration undoubtedly acted with greater force and effect.

In another experiment on a dog, detailed in the appendix, (Exp. A) I ascertained the amount of air respired before and after the division of the vagi, by means of an apparatus arranged for the purpose by Dr. Snow. Before the division of the vagi, when the breathing was somewhat hurried, the dog expired 900 cubic inches in $7\frac{1}{2}$ minutes, and in about 230 expirations; the respirations varied from 22 to 44 in the minute; and each expiration consisted, on an average, of 4 cubic inches. After the division of the vagi, the animal expired 900 cubic inches in $8\frac{1}{2}$ minutes, and in about 51 expirations; the respirations were 6 in the minute, and each expiration consisted, on an average, of about 22 cubic inches. We thus see, that although, after the division of the vagi, the number of respirations were diminished to about 1-4th, yet the volume of each expiration was five times as great, and the total quantity expired was nearly as great as before the division; notwithstanding that respiration was stimulated and accelerated while making the previous observation.

It is remarkable that certain mutilations of the nervous system, such as pithing, and the division of the vagi, while they arrest, or disturb, the ordinary respiratory movements, exalt or excite

certain extreme movements of respiration, such as gasping, and dilatation of the nostrils.

That the continuance of the respiratory movements after the division of the vagi is not due to volition, is evidenced by the experiments of M. Volkmann, M. Flourens, Dr. Reid, M. Longet, and Dr. Marshall Hall; those physiologists divided the pneumogastrics, and also removed the brain, yet the respirations, though infrequent, were still performed.

It is evident, indeed, that the par vagum in some way controls and regulates the movements of respiration, just as we have seen that the brain controls the reflex movements.

Although the movements of respiration may continue, even with increased power, after the division of the pneumogastrics, yet it is quite certain that the respiratory movements may be excited through their ageney. This is amply proved by the experiments of Dr. Hall and Mr. Broughton, and other physiologists.

Bichat observed that respiration was increased when he irritated the vagus; but this he attributed to the pain excited. Dr. Reid, however, found that even when an animal was under the influence of prussic acid, the respirations were increased by stimulating the vagi. In the first experiment in the appendix, on laying hold of the vagus, the respirations rose from 9 in 15 seconds to 20.

It is more particularly the expulsive or expiratory actions which are excited by stimulating the extremities of the vagus, diffused in the pulmonary and other mucous membranes. This is in harmony with Müller's important generalization, that the stimulation of any part of the mucous membrane excites an expulsive effort, directed upon the neighbourhood of that part; thus sneezing is excited by stimulating the nostrils, vomiting by stimulating the fauces, the expulsion of the fœtus by stimulating the vagina. In like manner, in Mr. Erichsen's, Dr. Reid's, M. Brachet's, and my own experiments, coughing was excited by stimulating the bronchial mucous membrane. Indeed, as M. Valentin, according to Müller, states, irritation of the pulmonary branches of the par vagum excites expiration.

I consider, indeed, that as each ordinary inspiration is excited reflexly by the influence of the circulation in the cutaneous capillaries on the cutaneous and other incident nerves, so each ordinary expiration is excited by the influence of the blood circulating in the pulmonary capillaries on the pulmonary branches of the par vagum.

During expiration, while the systemic capillaries receive the greatest amount of blood, the pulmonic capillaries receive the smallest amount of blood. On the other hand, during inspiration, while the circulation is the least vigorous and copious in the systemic capillaries, it is most vigorous and copious in the pulmonic capillaries. When the external pressure is removed from the lungs, by the expansion of the chest, air forced inwards by atmospheric pressure is admitted more freely into the air-cells, and blood forced onwards by the ventricular contraction is admitted more freely into the pulmonic capillaries.

I consider that the incident pulmonary branches of the pneumogastric are stimulated during inspiration, by the increased circulation in the pulmonary capillaries, and by the sudden exposure of the pulmonary mucous membrane to a purer and cooler atmospheric air, and that the reflex act of expiration is thus excited.

I consider, then, that the increased quantity and force with which the blood circulates during expiration in the systemic capillaries, stimulates the incident and especially the cutaneous nerves, so as to excite reflexly the next inspiration; and that the increased quantity with which the blood circulates during inspiration in the pulmonary capillaries, and the sudden impression of a cooler and purer air on the pulmonary mucous membrane, stimulate the incident pulmonary branches of the par vagum, so as to excite reflexly the next expiration. The inspiration has its usual source of excitement in the skin, during the expiration; and the expiration has its usual source of excitement in the lungs, during the inspiration.

I do not deny that the pulmonic branches of the par vagum may in some measure excite ordinary inspiration; but that they actually do so is certainly not proved. I know, indeed, that the pulmonic branches of the par vagum may be stimulated, like the other incident nerves of the mucous membranes, so as to excite a deep inspiration. Thus, on irritating the nostril, a deep inspiration is excited, followed by violent sneezing. On stimulating the vagina during labour, a deep inspiration is excited, followed by a violent expulsive expiration. So on stimulating the bronchial mucous membrane, an expulsive cough is excited, but that cough is preceded by a more or less deep inspiration.

In the experiments A and B, detailed in the appendix, as well as in others, when I passed a probe through an opening in the trachea,

downwards into the bronchiæ, I excited an expulsive effort, but such effort was invariably preceded by a deep inspiration. So long as I stimulated the bronchial mucous membrane by moving the probe freely about, I excited renewed deep inspirations, followed by expulsive efforts; the respirations being sometimes increased in number, sometimes diminished. If, however, I left the probe quiescent in the bronchiæ, the respirations were not perceptibly altered.

After the division of the vagi, the respirations were not in the slightest degree affected by moving the probe freely about in the bronchiæ.

If I passed the probe upwards into the larynx before dividing the vagi, I excited a cough or an expulsive effort, but such cough was in no instance preceded by an inspiration, even when the larynx was stimulated just at the end of an expiration. How beautifully special is the excitability of the incident nerves of the larynx. The stimulation of every other mucous membrane, as the vagina, the rectum, the neck of the bladder, the fauces, the nostrils, and the bronchial tubes, excites respectively, according to the part stimulated, the expulsion of the fœtus, the fœces, or the urine, vomiting, sneezing, or coughing; each expulsive effort being invariably preceded by a deep inspiration, so as to give additional purchase to the expiratory muscles, as well as, in sneezing and coughing, to flush the air-passages by the additional rush of air from behind, and in the acts of expulsion from the abdominal cavity, to compress the viscera by the descent of the diaphragm. Why is it that the stimulation of the larynx alone excites an expulsive effort that is not preceded by an inspiration? It is that the irritating gas or fluid which stimulates the larynx may be absolutely forbidden to enter the lungs, an event that in itself might prove fatal. (See p. 273).

The blood in the pulmonary capillaries is more charged with carbonic acid during expiration than inspiration. It seems probable, therefore, at first sight, that the blood then circulating is more stimulating than the more arterial blood circulating during inspiration. If this were so, it would give support to Dr. Marshall Hall's view, that the inspiration is excited by the excess of carbonic acid which accumulates in the lungs, and the pulmonary circulation during each expiration. The freshly oxygenated blood is, however,

even more stimulating to the incident nerves than the carbonized blood. This is proved by an experiment of Legallois. He pithed a rabbit, and in three minutes and three quarters it ceased to gasp. In four minutes and a half, when the carotids were black, and the heart active, artificial respiration was performed. Within 5 seconds the carotids were full and red; and in 15 seconds the gaspings were renewed. Here the oxygenated blood re-excited the gasping, which had ceased under the influence of carbonized blood.

If more blood, even although carbonized, circulated in the pulmonary capillaries during expiration than inspiration, then its increased quantity would more than make up for its less stimulating quality, and the pulmonary incident nerves would be more highly stimulated during expiration than inspiration; but, as we have already seen, the facts are directly opposed to this supposition, for there is less blood, as well as a less stimulating blood, in the pulmonary capillaries during expiration than inspiration. Besides this, the carbonic acid accumulates gradually in the air-cells and in the blood in the pulmonary capillaries during expiration. Now, reflex movements are not so readily excited by slowly increasing, as by sudden impressions. It is during inspiration, and not during expiration, that a sudden impression is made on the pulmonary incident nerves; since it is during inspiration that the cold air suddenly enters the lungs, and that the blood suddenly finds its way in an increased flow into the pulmonary capillaries. That blood, too, then becomes suddenly oxygenated, and so presents a rapid alternation from a state of torpor and carbonization in the pulmonary circulation during expiration, to a state of energetic vitality and oxygenation during inspiration, the latter condition being greatly more stimulating to the pulmonary incident nerves than the former.

There is every reason, then, to infer, that while the inspirations are ordinarily excited by the increased flow of blood stimulating the systemic, especially the cutaneous incident nerves during expiration; the expirations are ordinarily excited by the increased flow of blood stimulating the pulmonary incident nerves during inspiration, as well as by the colder and purer air, then in the air-cells.

In the experiment B, detailed in the appendix, perfectly rhythmical respiratory efforts were made, for two minutes after the trachea was closed by the grasp of the finger and thumb. This experiment

proves that the inspiratory movements do not depend on the alternate increase of carbonic acid in the lungs and pulmonary vessels during expiration, and diminution during inspiration; since tranquil respiratory efforts were made rhythmically, although the carbonic acid in the lungs went on progressively increasing; until at length, when its accumulation in the system as well as in the lungs was at the utmost, asphyxial convulsive respiratory movements were excited. It is to be observed, that these respiratory movements could not depend on the stimulation of the par vagum, since they were performed with equal regularity and force, after as well as before the division of the nerves.

Although the circulation is the ordinary excitor of respiration, yet in the cold-blooded, and the new-born imperfect warm-blooded animals, the respiratory movements may continue after the cessation of the circulation. This is instanced in Mr. Barlow's experiment, in which gaspings were renewed in the head of a decapitated eel, on its being immersed in warm water; and in the experiments of M. Legallois, on new-born rabbits, in which gaspings continued for twenty minutes after excision of the heart. When the adult warm-blooded animal is beheaded, gasping continues but for a very short period, the circulation being more necessary and efficient in exciting respirations in the adult than the young. In a series of experiments on adult linnets (see appendix D), I found that gaspings were excited by decapitation, and that they lasted about 10 seconds, while they continued for about 50 seconds, when the cervical spinal column was severed, but the circulation in the carotids continued. I also found that if, in the latter case, I compressed the neck so as to arrest the supply of blood to the head, the gaspings ceased in about 7 seconds. If, within two or three seconds of their cessation, I restored the circulation, the gaspings usually soon re-appeared. Here the carotids supplied the brain as well as the fifth pair in the face.

Dr. Reid's question, "Do the same excitations that occasion the muscular movements of inspiration operate in the production of the expiration which immediately follows, so that they are to be considered two stages of one and the same muscular action?" appears to be answered in the affirmative, in Mr. Barlow's experiment just referred to, and in Volkmann's experiment also, in which the respiratory movements continued 40 minutes after the excision of

of the lung. Indeed, the respiratory movements are rhythmical, and, like others of the rhythmical movements, it may be said that they are in a measure peristaltic. The heart's movements are rhythmical and peristaltic, beginning in the cava, ending in the ventricle; the respiratory movements may perhaps also be said to be peristaltic, beginning in the nostrils, passing thence to the glottis, and to the diaphragm and inspiratory costal muscles, and finally to the expiratory muscles. If the heart of the turtle be cut out, its movements, usually excited by the circulation, continue for hours; so with the movements of respiration, though usually excited by the circulation, they continue for a longer or shorter time after the circulation is cut off, especially in the cold-blooded animals.

On the causes which excite Respiration in Asphyxia.

If a stop-tap be tied into the trachea, and if the tap be turned so as to prevent the ingress or egress of air, a remarkable series of movements ensue. These movements consist in fruitless alternate, repeated, and rhythmical attempts at inspiration and expiration. These regular rhythmical movements were observed with minute exactness in the experiments A and B in the appendix.

Dr. John Reid has very accuratcly observed the order of the phenomena. At first the animal is quiescent, and makes rhythmical efforts to breathe; at the lapse of a minute and a half commence violent convulsive attempts at expiration. These struggling movements of expiration, alternating with movements of inspirations, last about a minute; then succeed heaving inspirations, more and more feeble and distant, alternating with expirations.

Dr. Edwards and Dr. Marshall Hall have shown that the animal becomes unconscious as the convulsions commence. Dr. John Reid erroneously supposed that consciousness did not cease until the convulsions ceased.

If the stop-tap be opened, at an advanced period of the process of asphyxia, the respirations if renewed are diminished in frequency, slow and heaving.

In the adult animal the respiratory movements cease in about four minutes; in a new-born animal they continue much longer. Legallois asphyxiated a new-born rabbit by submersion, and the respiratory movements continued for twenty-seven minutes.

The asphyxial respiratory movements are extreme; their character is peculiar. Every respiratory muscle is called into powerful action; the mouth and fauces being expanded to the fullest extent at each inspiration.

During the process, then, of asphyxia, the muscles are excited to action to a much greater extent and with much greater force than they are in ordinary respiration. It is therefore evident that the causes exciting the movements of asphyxial respiration are much more powerful than the causes exciting those of ordinary respiration.

We must here shortly consider what is the condition of the circulation during asphyxia. The successive labours of Bichat, Dr. John Reid, and Mr. Erichsen, have shown that during asphyxia there is greatly increased resistance to the flow of blood through the systemic as well as the pulmonic capillaries. Those capillaries are swollen and distended with the increased quantity of slow moving, dark, carbonized blood. The force with which the blood is propelled along the arteries is at first greatly augmented, especially during the struggles of the animal, but also even after those struggles have ceased; gradually the circulatory force falls below even the normal standard.

We have already seen that Volkmann considers that the respiratory movements, reflex in their nature, are excited by carbonic acid circulating in the blood throughout the organism.

This view, which I have shown to be erroneous as regards ordinary respiration, is, I conceive, perfectly correct as regards asphyxial respiration.

During ordinary respiration the blood circulating in the capillaries is oxygenated, and is comparatively small in quantity; while during asphyxia the blood is excessive in quantity, and contains carbonic acid in excess.

The poisoned and augmented blood circulating in the capillaries during asphyxia, is more stimulating to the peripheries of the systemic and pulmonic incident nerves than the healthy arterial blood present during ordinary respiration. Consequently, while the minor stimulus of arterial blood only excites the movements of ordinary respiration; the major stimulus of the augmented carbonized blood excites the increased and extraordinary movements of asphyxial respiration.

As I have already shown at p. 303 and seq., the increased movements of asphyxial respiration are not due alone to the increased excitation of the incident nerves, but are due also to the withdrawal of the control of the brain from the reflex and direct spinal functions. Indeed, the withdrawal of the control of the brain over the reflex and direct spinal functions, while those functions are themselves exalted, must be assigned as the cause of the violent convulsive movements which take place during rapid asphyxia. I say during rapid asphyxia, for if the asphyxia be very slowly brought about, no such convulsions are excited; the inspirations are however still characterized by the wide gasping of the mouth, palate, and fauces, and the extent of the muscular movements.

It is to be remarked that the inspiratory and expiratory movements are equally alternate and rhythmical, in asphyxial, as in ordinary respiration. It follows that the cause of the inspiration may then also be expected to alternate with the cause of the expiration.

In ordinary respiration, as I have more than once stated, I consider that during each expiration the augmented force and flow of arterial blood in the systemic capillaries, stimulates the systemic incident nerves, and excites the reflex movements of inspiration; while, during inspiration, the increased amount of arterial blood in the pulmonary capillaries stimulates the pulmonic incident nerves, and excites the reflex movements of expiration.

It appears to me that a like chain of alternate increase and diminution, first in the systemic, and then in the pulmonic circulation, causes respectively by the very alternation, first the inspiration, and then the expiration.

In asphyxia, the greatest amount of blood is sent with the greatest force to the systemic capillaries during the expiratory effort; consequently, during expiration, the incident systemic nerves are stimulated, and the reflex inspiratory movements are excited. On the other hand, during the effort at inspiration, owing to the enlarged space in the chest, caused by the expanding force of the inspiratory movements, the lungs contain a greater amount of carbonized blood, consequently, the pulmonic incident nerves are stimulated, and the next expiration is excited.

Carbonic acid is not in itself, I conceive, more stimulating to the incident nerves than oxygen; in fact, it is not, as I have already shown, so stimulating; but one stimulus, as we have already

seen, alternates with another. Oxygen first stimulates, and then exhausts excitability; carbonic acid re-stimulates the excitability, previously exhausted by the oxygen, and then again in its turn exhausts the excitability, which may be again aroused and again exhausted by oxygen.

Oxygen is however more stimulating, and more permanently stimulating, than carbonic acid; but the one and the other will equally prove a stimulus in its turn.

The respiratory phenomena of chronic asphyxia differ, as I have already said, from those of rapid asphyxia, in the want of the violent convulsive expiratory movements. Those violent movements are wanting, I conceive, in chronic asphyxia, owing to the gradual deprival of consciousness, and the gradual increase of the carbonic acid in the blood. The reflex and direct spinal functions are exhausted or lowered simultaneously with the removal of the cerebral control on the principle illustrated at page 310.

It is painfully interesting to notice asphyxial respiration creep slowly on in the dying, especially in those dying from bronchitis or pulmonary affections. The carbonized blood loiters in the cutaneous capillaries, and darkens the tumified skin. The inspiration becomes more heaving and slow; more and more of the muscles of inspiration are put in action; the nostrils dilate widely. At length the mouth gasps; the tongue is protruded at the tip, and brought forwards and downwards at the base; the palate is raised; and the glottis is expanded to the full by the wide inspiratory separation of the vocal chords.

Even when the air can only enter through an artificial opening in the trachea, the gasping movements of the mouth and nostrils take place.

Finally, after consciousness disappears, after the eye becomes fixed and glazed, after the muscles of the ribs cease to act, after the diaphragm itself ceases to move, and after even the nostrils have ceased to dilate, the mouth is still opened; the upper jaw being raised during a few frightful gasps, while at the same time the tongue is lowered, the palate raised; and these strange and ghastly movements are made sometimes at remote intervals for a minute, or even more, without any responsive expansion of the chest.

These last inspiratory movements, continuing perhaps after the circulation has ceased, are necessarily excited through the fifth pair;

death has stolen along the spinal system from below upwards; the last nervous arc to die is the highest, that arc embracing the fifth pair, the reflex movements taking effect from the incident branches of the fifth, through the nervous centre, and back along the motor branches of the fifth, so as to retract the angles of the mouth by means of the buccal muscles, after the reflex movements of the nostrils have ceased to take effect along the seventh pair.

The mouth is expanded during asphyxial inspiration, whether the asphyxia be rapid or chronic, by the simultaneous elevation of the upper jaw and depression of the lower jaw; the upper jaw is elevated by the muscles at the back of the neck, which pull down the occiput. I regard this asphyxial gasping as a most unfavourable and threatening sign. I have very rarely indeed seen persons recover who have exhibited this sign for some time; and I have watched, with a painful interest, such persons for days struggling in vain for recovery.

Whenever the organic processes are at work, circulation and respiration are active. The respirations are increased or diminished in proportion to the energy of the circulation and the activity of the organic functions. Whenever, wherever, and however the circulation is excited, whether by the activity of the organic functions, by exercise, by mental emotions, by the circulation of poisoned or stimulating blood, or by external stimulation, the respirations are proportionately increased. The circulation in the capillaries stimulates the peripheries of the incident nerves, and so excites the respirations in a reflex manner. Respirations are excited reflexly whenever the incident nerves are stimulated by the circulation, or by any other means, whether in the lungs or the system, the skin, the internal organs, or the general frame-work. The incident nerves are most abundant in the skin, and therefore the reflex respiratory movements are excited most frequently through the medium of the cutaneous incident nerves, stimulated by the cutaneous circulation. This is particularly manifested when respiration is quickened by the stimulation of the surface, as by the exposure of the surface of the cold-blooded animals to increased warmth, and of the warm-blooded animals, within certain limits,

to increased cold; the incident nerves being stimulated, and the circulation and respiration roused, in one class by warmth, in the other by cold. But if torpor be induced in the warm-blooded animals by long continued cold or inanition, then their nervous energies are lowered, and the respirations are diminished by increased cold.

The circulation of oxygenated blood is most abundant and energetic in the system during inspiration, in the lungs during expiration; and I conceive that the inspirations are usually excited reflexly by the stimulation of the systemic, especially the cutaneous incident nerves by means of the systemic circulation during expiration; and that the expirations are usually excited during inspiration by the stimulation of the pulmonary incident nerves by means of the pulmonary circulation, as well as by the sudden impression of the purer and cooler inspired air.

Deep inspirations are excited by excessive stimulation of the cutaneous nerves, and violent expirations, or expulsive efforts, by excessive stimulation of the pulmonary nerves, or indeed of the nerves distributed over any mucous membrane. Inspiration may, however, be excited as a precursor to the expulsive effort, and respiration may be increased by the stimulation of the bronchial as well as of any other mucous membrane, except that of the larynx; and expirations may be excited by the excessive stimulation of any of the incident nerves of the system.

Expiration may follow inspiration, and inspiration expiration, without a special excitation for each act; the respiratory movements being indeed rhythmical, and, I conceive, peristaltic.

Oxygen and oxygenated blood are in themselves more stimulating to the incident nerves than carbonic acid and carbonized blood; but blood when carbonized tends to accumulate in the capillaries, and when it does so, it stimulates the incident nerves and the nervous centres to an inordinate degree; consequently during asphyxia, violent convulsive respiratory movements are excited.

APPENDIX.

Experiment A.—In crder to observe the effects of division of the vagi on respiration, I performed the following experiment on a dog, when I had the advantage of Dr. Snow's and Mr. Marshall's assistance.

After the animal was chloroformised, and the trachea was opened,

At 4 h. 15 min. the respirations were 12 in 15 seconds, 23 in 30 seconds.

4 h. 15 min. 16 secs. chloroform was administered through the opening in the trachea. The respirations were not quickened just at first; they were, however, speedily much accelerated.

At 4 h. 15 min. 45 secs. the respirations were 35 in 15 seconds.

4 h. 16 min. 30 secs. ,, ,, 44 in 15 seconds.

4 h. 17 min. the respirations were scarcely perceptible. The chloroform was removed.

At 4 h. 19 min. 30 secs. a catheter was passed through the opening in the trachea down into the bronchiæ. The respirations were 25 in 15 seconds; the expirations became loud, forced, and noisy.

At 4 h. 20 min. the catheter was withdrawn; respirations, 15 in 15 seconds, the expirations being quiet.

At 4 h. 21 min. 30 secs. respirations, 15 in 30 seconds.

4 h. 22 min. a catheter was inserted into the bronchiæ, when loud coughing expirations were excited. Respirations, 22 in 30 seconds. After this the respirations were successively 9 and 10 in 30 seconds. On re-administering chloroform the respirations gradually rose to 49 in 15 seconds.

At 4 h. 30 min. is under the influence of chloroform. Cutting excites no sensation. On putting a catheter down into the bronchiæ strong expirations are excited: a slight cough is excited on passing it upwards to the larynx. Putting the catheter downwards into the bronchiæ excites, first a deep inspiration, and then a forcible expiration, the respirations being 16 in 15 seconds. On passing it upwards to the larynx, a forcible expiration is excited, which is not preceded by an inspiration.

At 4 h. 46 min. respirations 10 in 30 seconds.

4 h. 46 min. 30 secs. a balloon was attached to the trachea, holding about 900 cubic inches, provided with valves, under the direction of Dr. Snow, and so arranged that all the expired air was sent into the balloon. After the balloon was tied on, the respirations during successive periods of 30 seconds were 13, 14 somewhat blowing, 18 much deeper, 17 somewhat blowing, 19, 22, the animal then struggled a little, and was afterwards again quiet, the respirations falling to 11 in 30 seconds.

At 4 h. 54 min. the balloon being filled (in 7½ minutes) was withdrawn; after its removal the respirations were 17 in 15 seconds.

Soon after 5 o'clock the respirations were steady and regular, 9 in 15 seconds. On laying hold of the vagus, the respirations rose to 20 in 15 seconds.

At 5 h. 22 min. one vagus was divided; the animal ceased to breathe for a time, and then took a deep inspiration; the respirations were then 10 in 15 seconds. No palpable effect was excited on pinching either the upper or the lower end of the divided nerve.

When the respirations were 7 in 15 seconds, the catheter was introduced into the trachea, with the effect of exciting cough, the respirations being 5 in 15 seconds.

On pinching the undivided vagus, coughing was excited.

At 5 h. 27 min. 50 secs. the opposite vagus was divided; the respirations fell to 4 in the minute. The creature gasped widely at each inspiration.

Putting the catheter down into the bronchiæ excited no movement of any kind. There were then from 5 to 6 respirations in a minute.

The balloon (holding 900 cubic inches) was re-applied to the trachea, and was filled in 9½ minutes, the respirations being regularly 6 in the minute during the whole period of inflation.

On a second occasion the balloon was filled in 8½ minutes.

Subsequently, chloroform was applied over the opening in the trachea.

About 1 minute after the commencement of the inhalation of chloroform the respirations were 4 in 15 seconds; they were 9 in the next 15 seconds; and in the successive periods of 15 seconds they were 16, 18, 27, 36, 34; after this, the chloroform being removed, the respirations fell to 22, 19, 17. About this time the chloroform was renewed; the respirations rose from 20 in 15 seconds to 33. Finally, the chloroform was given in larger doses; the respirations fell progressively during each 15 seconds from 30 to 25, 21, 21, 19, 12, 18, 6 (20?), and finally to 3 in 15 seconds, that being the last record before the creature's death.

Experiment B.—The following experiment was performed on a cat; present, Dr. Snow and Mr. Marshall:—

When it was being chloroformised in a jar, it did not gasp; its nostrils were red; its breathing was slightly convulsive. It sank powerless to the bottom.

When under the influence of chloroform the trachea was opened; the respirations were 25 in 30 seconds. On putting a tube down into the bronchiæ, a deep inspiration was excited, and the expirations were more prolonged; the respirations were 7 in 15 seconds; after withdrawing the tube, during the second quarter of a minute, the respirations were 10 in 15 seconds. They were 18 in the next, and 14 in the next 30 seconds.

On passing the tube up to the larynx, a start and an expiration was excited, but this was not preceded by an inspiration, even when the larynx was irritated at the end of an expiration, and when in the ordinary course, an inspiration would take place.

Soon after the renewed administration of chloroform, the respirations were ... ... 14 during 15″.

The trachea was then closed by compressing it firmly between the finger & thumb.	the respirations were	9	during the 1st	15″	after closing the trachea.
	,, ,,	7	,,	2nd 15″	,,
	,, ,,	8	,,	3rd 15″	,,
During the 6th, 7th, and 8th periods of 15 seconds the respiratory efforts were more powerful.	,, ,,	8	,,	4th 15″	,,
	,, ,,	8	,,	5th 15″	,,
	,, ,,	6	,,	6th 15″	,,
	,, ,,	6	,,	7th 15″	,,
	,, ,,	3	,,	8th 15″	,,
At the end of two minutes the air was re-admitted into the trachea.	,, ,,	0	,,	1st 15″	after re-opening the trachea.
	,, ,,	9	,,	2nd 15″	,,
	,, ,,	8	,,	3rd 15″	,,
	,, ,,	8	,,	4th 15″	,,
At the end of a minute the trachea was again closed.	,, ,,	25	,,	1st min.	after closing the trachea.

At the end of the first minute the animal gasped, and threw back its head, the respirations were 10 during the first half of the second minute.

At the end of 90 seconds the creature stretched itself, and the trachea was again opened.

After the trachea was again opened, the respirations were from 9 to 10 in 15″.

5 h. 7 m. One vagus was divided, the respns. were	7	in the	1st	15″	after the division of the vagus.
,, ,, ,,	6	,,	2nd	15″	
,, ,, ,,	5	,,	3rd	15″	
The trachea was then again closed, ,,	5	,,	1st	15″	after closing the trachea.
,, ,, ,,	5	,,	2nd	15″	
During the 3rd 15 seconds the animal began to gasp, ,,	5	,,	3rd	15″	,,
During the 4th 15 seconds the gasping increased, ,,	5	,,	4th	15″	,,
During the 5th 15 seconds the gaspings were still wider, ,,	5	,,	5th	15″	,,
At the end of 1 min. 15 secs., the trachea was opened, and the creature inspired very deeply, ,,	6	,,	1st	15″	after opening the trachea.
,,	5	,,	2nd	15″	
,,	4	,,	3rd	15″	

The catheter was now passed into the bronchiæ without producing any effect.

Immediately before the division of the second vagus, the respirations were 4 or 5 during 30″.

5 h. 13 m. The other vagus was divided. The respirations, not gasping, were 5 during the 1st 15″ after the division of the second vagus.

The creature then struggled, after which the respirations were 8 during the next 10″ after the division of the second vagus.

The respirations soon fell to 5 during 30″ after the division of the second vagus.

The trachea was then closed; the respiratory efforts were 7 during the 1st 30″ after closing the trachea.

At length the animal began to struggle, and gasped during each attempt at inspiration.

The trachea was again opened, when the lips separated slightly during each inspiration. The respirations were 7 during 30″ after opening the trachea.

The trachea was again closed.

The creature at first gasped slightly, resp. efforts	4	during the	1st 15″	after closing the trachea.
The gasping increased, respiratory efforts	4	,,	2nd 15″	
The gasping still increased, ,,	5	,,	3rd 15″	
The animal then began to struggle ,,	4	,,	4th 15″	

The trachea was then opened.

The creature gasped exceedingly, the resp. were	8	,,	1st 15″	after re-opening the trachea.

Under the use of chloroform the gasping ceased, and the animal soon died.

Experiment C (on a Pigeon.)

I removed the brain from a chloroformised pigeon, and then decapitated it.

After the gasps had ceased, while Dr. Snow inserted one electro-magnetic wire into one nostril, I inserted the other wire into the opposite nostril, when the beak opened and closed in rapid quivering alternation. I immediately divided both fifth pairs, leaving the seventh intact; and we then re-applied the wires to the nostrils without producing any effect. I then applied one wire to the medulla, and so excited gasping movements of the beak.

I made several unsuccessful attempts to repeat this experiment.

Experiments D (on Linnets).—Present, Dr. W. T. Gairdner, of Edinburgh, Dr. Snow, and Mr. Marshall.

I decapitated a linnet, it afterwards gasped 8 times, for the last time at the end of 10″.

,, another linnet	,,	9	,,	5″.
,,	,,	14	,,	14″*
,,	,,	14	,,	14″.

I cut across the spinal column high up in the neck in another, leaving the front part of the neck intact, so that circulation went on through the carotids.

The bird afterwards gasped . . . . 58 times, the last time at the end of 50″.

I repeated this expt. on another linnet, it gasped 40 times, the last time at the end of 25″.

,,	32	,,	30″.
,,	21	,,	15″.

There was more blood lost in the three latter of these four experiments than in the first.

I cut across the spinal column in a like manner in another linnet; it gasped seven times during the first 5 seconds. I then compressed the neck firmly between my finger and thumb, so as to stop the circulation in the carotids; at the end of eight additional seconds the gasps had ceased; I then removed the pressure so as to restore the carotid circulation, when the gasps returned, and were repeated nine times.

This experiment was repeated several times. The gaspings usually ceased about 7 or 8 seconds after the commencement of the pressure. In some instances the gaspings were renewed after restoring the circulation, by removing the pressure, in others they were not.

I have been favoured by Dr. W. T. Gairdner, of Edinburgh, with the notes of some experiments on rabbits, performed by him

* It gasped for the last time after a pause of 4 seconds.

in 1845, with a view to ascertain the physiological effects of obstruction of the arteries leading to the head. The experiments were eight in number, and were supplementary to those of Sir A. Cooper, in Guy's Hospital Reports, vol. i., being, however, intended to show more particularly the effects of the obstruction of these arteries upon the respiration and general circulation.

Experiment 1 *(on a Rabbit).*—The pulse at the heart, at the commencement of the experiment, was about 32 on an average in the quarter of a minute,* and the respirations were 26 in the same space of time.

The carotid arteries were then tied, and after this the pulse was 38. Respiration, 17 to 18. The functions of the animal were not at all impaired.

The vertebrals were then compressed on both sides of the vertebral column, the trachea being carefully excluded. A few convulsive gasps followed, and in about 20 to 30 seconds there were violent convulsions of the whole body. On the ceasing of the convulsions, at one minute after compression, the pulse was 16 per quarter minute; the nostrils had ceased to move. The heart continued to beat for about 7 minutes.

Experiment 3 *(on a small Rabbit).*—Before commencing experiment, pulse 40 per quarter of a minute, respirations 24; after tying carotids, pulse 35, respirations 16; heart acting very strongly.

The vertebrals were now compressed.

In ½ a min. after compression, strong convulsions; pulse gone.
1 min. convulsions continue; pulse intermitting and slow, cannot be counted.
1½ min. pulse 44, weak; no respiration.
2¼ min. pulse 40 to 50, very weak; slight motion of whiskers; another convulsion.
3½ min. pulse scarcely perceptible.
4 min. pulse ceased; motion completely gone.
5 min. slight thrill at heart again.
6 min. pulse again quite imperceptible; surface cold; no motion.

The compression was now removed, and after about a minute more the thorax was laid open. As a comparative observation, the thorax of a rabbit asphyxiated by drowning was also opened. In this latter instance there was great congestion of the veins of the neck, and of the intestines; in the heart, the right ventricle and auricle were found gorged with venous blood; the left ventricle was empty and hard, being, in fact, spasmodically contracted, so that its cavity was obliterated. In the rabbit which was the subject of experiment, the heart was found replete with blood in all its cavities, both sides being about equally distended; the auricles were still inefficiently

* The pulse and respirations were always counted by the quarter of a minute.

contracting, and the ventricles pulsated slightly on exposure. The venous system was notably less congested than in the asphyxiated rabbit, and the lungs were somewhat paler.

Experiment 5 *(on a moderate-sized Rabbit).*—At commencement, pulse 27 per quarter of a minute; respiration 16.

After tying the carotids and inserting a tube in the trachea, pulse 30, respiration not noted.

On the vertebrals being compressed, there were powerful convulsions of the trunk and extremities.

½ minute after compression of vertebrals the pulse was gone, and there were no respiratory movements.

Artificial respiration was now employed.

1 minute after compression, pulse returned, but intermitting.

1½ minute there was a barely perceptible thrill at the heart, and within a minute more it was gone.

Artificial respiration was kept up till the eighth minute, but without return of the pulse. The pressure was then removed, and the experiment discontinued.

On opening the thorax the auricles were found pulsating pretty strongly. The heart was distended in all its cavities with blood, which on the left side was very florid, much more so than in the preceding experiments; lungs pale, integuments exsanguine.

Dr. Gairdner writes, "it would be very desirable that similar experiments should be repeated on other animals, and with every precaution against fallacy. But the following conclusions appear to be deducible from them, without much risk of error.

"1. The tying of both carotids in the rabbit, all other parts being left intact, is followed by—

"*a.* A distinct and invariable lowering of the number of respirations, to the extent of from one-third to one-sixth of the previous number.*

"*b.* A lowering in some cases, but in others no change, in some even an elevation, of the number of pulsations of the heart.

"*c.* Little or no perceptible effect on the general condition of the animal in other respects."

	Before commencing experiment.		After tying carotids.		
* 1st experiment.	Pulse 32	Resp. 26 ...	Pulse 38	Resp. 18	During fifteen seconds.
3rd ditto.	,, 40	,, 24 ...	,, 35	,, 16	
4th ditto.	,, 33	,, 22 ...	,, 29	,, 19	
5th ditto.	,, 27	,, 16 ...	,, 30	,,	
6th ditto.	,, 29	,, 19 ...	29–30	,, 16	
7th ditto.	,, 33	,, 17 ...	,, 26	,, 14	
8th ditto.	,, 39	,, 25 ...	36–40	,, 24	

In experiment 2 the vagus nerve was accidentally included, on one side, in the ligature; and there is some doubt as to whether the compression of the vertebrals was accurately effected. The results are therefore not here given.

"2. The ligature of both carotids and compression of both vertebrals is followed by—

"*a*. Absolute suspension of the respirations, after one or two convulsive gasps. In no instance, except the doubtful one in Experiment 2, did they return, when compression was maintained.

"*b*. Extreme diminution, both in force and frequency, of the heart's pulsations, amounting sometimes to absolute prostration, but followed in two or three minutes by partial recovery; the pulsations returning sometimes to their original frequency, but never regaining an effective degree of force for carrying on the circulation.

"*c*. The passage of dark blood through the lungs into the left heart, or the commencement of the phenomena of a secondary asphyxia, which however is modified by the weak state of the left heart.

"*d*. General convulsions, lasting a few seconds, followed by complete insensibility and cessation of the reflex movements.

"3. The modification of these results by artificial respiration is very slight. In no instance did it succeed in restoring the heart's activity, nor in recalling any of the phenomena of nervous action, notwithstanding that the blood in the left heart was found florid on dissection. The prostration of the heart's action, upon which death evidently depends in these experiments, is therefore not due in any degree to *asphyxia*, but is of the nature of pure *syncope*. It is, moreover, a syncope in all probability absolutely dependent on the arrest of the circulation in the arteries leading to the head, as is proved by the recovery of the animals in Cooper's experiments, on removing the pressure within a limited period."

ON GANGRENE OF THE LUNG.

BY FRANCIS GEORGE PROBART, M.D., Edin.,

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It having happened to me to treat several cases of the comparatively rare disease, *gangrene of the lung*, and in every instance successfully, by an undeviating practice of much simplicity, I feel assured that you will permit this communication to be read at the eighteenth anniversary of our Association.

It may probably be felt that it was my duty to have announced this sooner; and I have, indeed, often been so urged by some of my professional coadjutors, but have preferred to delay publishing my success, and its means, only out of regard to the commendable jealousy and caution with which proposed new remedies are received, and that I might be able to multiply indubitable facts, and so to secure professional credibility and confidence.

I have had, since the adoption of my treatment, nine cases, but shall notice particularly only two of them; the first to explain the incidental suggestion of the remedy to my mind, and the second, when considered in connection with that and the others, as proving, almost to demonstration, its specific sanatory influence.

I was called in the night to visit a gentleman of considerable distinction, a few few miles from Bury, whom I at once found to be labouring under partial gangrene of the right lung. It had been treated, and I thought naturally, for acute bronchitis by the medical gentleman whom I found at the bedside, and who had been in attendance for two or three days, and was now summoned, as well as myself, in consequence of the symptoms having become aggravated in a measure that greatly alarmed the patient and his family. Bleeding from the arm had been practised shortly before my arrival, but without alleviation of the dyspnœa and violent paroxysm of cough, for which it was intended; these symptoms, on the contrary, were represented as having increased. The pulse, as I think it will constantly be found in this disease, was quick and

feeble; the surface of ordinary temperature; countenance anxious, pale, and ghastly; tongue moist and white. His cough continued to occur in paroxysms, of painful severity, when, with much labour, a large quantity of frothy fluid, slightly tinged pink, was expectorated, emitting a stench indescribably fetid, and all but insupportable, making it imperative to throw open all the doors and windows, as well of other parts of the house as of the apartment wherein our patient lay. The sputa varied much in consistence and colour as the case advanced. Auscultation, before a paroxysm, discovered a loud mucous râle, resembling that of chronic bronchitis, over a considerable space of the right side of the chest, while immediately afterwards little was to be heard, except in a circumscribed spot under the scapula, of not more than two square inches in extent, where a subdued but distinct crepitation was audible.

My treatment of the case for three weeks was confined to tonic, palliative measures, and the attempt, by all nutritive means, to support my patient's vital powers, which seemed to be hourly languishing, although his appetite was so little impaired as to admit of his partaking amply of animal food, and drinking as much as a bottle and a half of port wine in twenty-four hours, besides porter. His flesh, neverthelcss, entirely vanished; and his strength had so completely left him that, though only a few weeks since a heavy, hale man, he was now carried about in the arms of his butler.

Having, as I thought, exhausted all remedial measures, and the invalid and his family all and equally despairing, I at length urged them, for the comfort and satisfaction of all parties, to permit me to obtain assistance; and a distinguished physician of London, of my own selection, saw him the succeeding afternoon. This eminent person quickly recognised the ordinary signs of pulmonary gangrene; but so limited was the space where any morbid sound could be heard that, although one amongst the earliest practitioners in the metropolis who sought the employment of the stethoscope in the investigation of pectoral disease, and at this time none more dexterous than himself in its application, it occupied him a considerable time to discover the spot. I mention this fact only to show what formidable general havoc we have in this appalling malady from so limited a source.

My learned consultant, like the rest of us, saw no prospect of saving the patient's life, and accordingly took his leave of him and

his family, holding out no hope; and having observed that he was unable to suggest any means in addition to those that were being practised, did not even write, nor dictate a prescription.

Two days subsequently, my patient happening to see me while at luncheon eat freely of salt, made the remark, that *for five years he had wholly abstained from its use at meals, until at length he had acquired an invincible disgust for it!* This curious fact at once struck me as of probable importance in the origin of his case; and, after some consideration, I was strongly impressed with the notion that the disease, whether originating or not through the necessary diminution, thus brought about, of the requisite quantity of that active substance in the blood, might admit of modification from its employment as a remedial agent. Accordingly, I lost no time in administering the chloride of sodium, in as large and frequent doses, suitably combined, as could be tolerated. I added to each dose of about two scruples ten grains of chlorate of potash, in two ounces of the compound decoction of sarsaparilla; at the same time I directed the frequent inhalation of chlorine.

In two or three days we were all flattered that there was improvement; and by the end of a week this was so apparent as not to be mistaken, and we were cheered with a sanguine belief that a remedy had been hit upon to save our patient's valuable life. So rapid was now his progress in recovery, that in a few more days he went out in his carriage, and shortly after took his favourite exercise on horseback, ultimately resuming, and continuing for some years to discharge his duties as a Clergyman, as well as those of a Magistrate and Chairman of Quarter Sessions.

Although this gentleman drunk, as I have already said, a bottle and a half of port wine in twenty-four hours, its effects as a stimulant were not appreciable until he commenced with the salt; when, gradually, as this was working its healing agency through his system, he found it necessary to diminish the allowance, until at length he could take no more than his wonted quantity when in health.

The subject of the second case to which I proposed to allude, and which is likely to be welcome to the Association, was a farmer, a fine young man, about 21 years of age, of great respectability, a lover of field-sports and other active pursuits. His case, as well as the others I have met with, presented all the prominent phenomena

of the foregoing one; but it gave me even more anxiety than it, because there were for many days a total want of appetite, and an intolerance of the saline treatment, equally as of nutrient ingesta. Confident, however, in the sovereignty of the measure, and seeing no alternative but a fatal termination without it, I essayed to exhibit the chloride of sodium, by means of the carbonate of soda and hydrochloric acid, in the state of effervescence, and with marked advantage; but as we were shortly obliged to abandon this plan also, my only resource then was an external application of it. The patient was, therefore, ordered the frequent use of baths of a strong solution of salt, and to be well rubbed after each with towels, which had been immersed in a still stronger (saturated) solution, and dried. The expedient answered beyond my expectations, for decided improvement immediately followed, and our young friend, whose life was several times despaired of by all but his medical attendants, finally recovered, and has remained well up to this time, eighteen months since the attack. I must observe that he continued at intervals to take very small doses of the chloride with the chlorate, either in decoction of bark or the compound decoction of sarsaparilla, and inhaled chlorine as often as his strength permitted, which was sustained by as much as could be borne of Port wine, jellies, broths, oysters, and the like.

In accomplishing the restoration of this young man, I had the efficient assistance of my intelligent and experienced friend, Mr. Jones, of Melford, to whose confidence in the method of treatment (for he had attended with me another of my cases), and his assiduity and precision in carrying it out, the success was mainly attributable.

No one who has not had personal experience of this disease can form a notion of its almost insupportable loathsomeness, and of the consequent difficulty of standing by the sufferer during a paroxysm of cough. He may drink brandy, smoke tobacco, take snuff, resort to chloride of lime, or any other subterfuge for assuaging his disgust, but in vain; and nothing but a sense of duty to the patient will enable him to bear up against it. Often, too, these attacks are of long duration, and full of painful anxiety to the subject of them, and all around him, from an apprehension of suffocation.

Although I have been physician to the Suffolk Hospital for

nearly twenty-four years, during which period 27,000 patients have been admitted, I have not there met with a case of gangrene of the lung, nor have I seen it in any of the great hospitals, either in Great Britain, or on the continent; and as all my cases have been subjects in easy circumstances, I cannot help indulging an opinion that the poorer classes are comparatively exempt from the disease, and, if so, that their immunity from it may be ascribed to their known larger dietetic consumption of salt. The facts I have here stated, and which I feel confident will hereafter be confirmed in the experience of others, go far to support the views of the immortal Laennec, on the nature of this terrible disease. That author in his "Treatise on the Diseases of the Chest," as translated by Dr. Forbes, writes—

"Gangrene of the lungs can scarcely be ranged among the terminations of pulmonary inflammation, and still less can it be considered as the consequence of its intensity; since we find in cases of this kind the inflammatory character very slightly marked, as well in regard of the symptoms, as of the engorgement of the pulmonary substance. It would on the contrary seem, in most cases, to approach the nature of the ideopathic gangrenes,—such as the anthrax, malignant pustule, pestilential bubo, &c.,—diseases in which the inflammation surrounding the gangrenous spot seems to be rather the effect than the cause of the sphacelus." Page 207, Vol. II.

The exciting causes of pulmonary gangrene have seemed, in my own experience, very obscure. The patients themselves have mostly attributed them to getting wet, or to a cold taken in some other way. However this may be, the symptoms it commences with are so slight as at first to attract little attention; but, at length, pain in some part of the chest, blood-stained expectoration, or the fetor of the breath, rouses the subjects fears, and sends him to his medical adviser. The proximate cause, however effected, must, I humbly think, be considered a deteriorated condition of the blood. But I am not without hope that the matter of this paper may elicit such a philosophic inquiry into its pathology as shall result in a satisfactory solution of the question.

CASE OF PLASTIC BRONCHITIS.

BY HUMPHRY SANDWITH, M.D.,

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Thomas Hebblewhite, aged 48, a mariner, of a strumous and lymphatic habit, rather under the middle size, stout and muscularly made, with tendency to obesity, formerly habitually intemperate and drinking spirits to excess, was attacked about the beginning of April, whilst at Lynn, with what he termed a severe cold, but which was not traceable to wet or other obvious cause. For this affection he was bled, leeched, and blistered, with apparent advantage. He had, before that time, enjoyed for the most part average good health; nor was he aware that any of his relatives had been consumptive.

I said he was attacked with a severe cold in the beginning of April, 1850. He did not consult me before the 20th of May, when he was manifestly suffering from serious chest affection. The symptoms were those of sub-acute bronchial inflammation, with dyspnœa, and so feeble a respiratory murmur in the lower part of the right lung as led me to suspect tubercle. I prescribed eight leeches and a blister, and put him under saline treatment, with antimony and ipecacuanha. As he lived thirty miles off, I did not see him again until June 3rd, when his surgeon, Mr. Raines, of Newport, accompanied him, who told me that a few days previously Hebblewhite had expectorated, during severe paroxysms of coughing, several pieces of tough, solid substances, of a cartilaginous whiteness. I still found but little air entering the lung below the right scapula, with dulness on percussion. A loud and large mucous râle also, more like the hoarse note of the raven than the cooing of the dove, accompanied both inspiration and expiration, but especially

the latter, in every other part of the right lung,* with signs of slighter chronic bronchitis in the left lung. I requested him to be moderately cupped below the right scapula, to have a large blister *inter scapulas,* and to have the entire chest rubbed night and morning with a strongly ammoniated terebinthinate liniment. The saline, antimonial, and ipecacuanha treatment was continued; and, as he complained very much of a distressing suffocative cough at night, he was ordered two grains of ipecacuanha with one quarter of a grain of muriate of morphia every night at bed-time. On the evening of the same day, whilst in the railway carriage, he expectorated, after most convulsive efforts, a large mass of true plastic sputa, in an aborescent shape, and forming a cast of the bronchial tubes. This substance had a peculiar and almost pearly whiteness, answering to the γαλακτωδεα or "white milky concretions," in a case described by Hippocrates, and quoted by Dr. Mason Good.† On the same night also, after severe coughing, a large quantity of thin, yellow, purulent fluid was thrown off, which was so copious as frequently to gush through the mouth and nostrils at once. This latter fluid I did not myself see. In a few days the puriform fluid ceased, and the polypoid or plastic substance began again to be evacuated, and has continued to be discharged at intervals in greater or less quantity up to a late period. A viscid white mucus, sometimes copious, at other times scanty, has accompanied these discharges; and relief from "the stuffing" (to quote the patient's language) has appeared much the same whether the expectoration of mucus was copious or scanty. The intervals between the discharges of plastic lymph have varied from one day to three or four days. Emetics of antimony and ipecacuanha constituted an important part of the treatment whenever the suffocative paroxysms accompanying the detachment of solid sputa imperatively

* In a similar case, recorded by Dr. Cane, in the *Dublin Medical Journal*, he says,—"But the râle sound and dove-coo are heard over the chest, blended with an occasional sound which I never heard in any other case, which conveys the distinct sound of a body moving with inspiration and expiration, a sort of rubbing sound, but not the frottement." Vol. xvii., p. 119.

† And at length, before he died, this patient expectorated οἷον ἐκ μυξης μυκητα, ξυνεστηκητα, λευκῳ φλέγματι περιεχομενα, "firm mucus-like excrescences, surrounded with white phlegm."—Dr. M. Good's "Study of Medicine." Vol. ii., p. 430.

demanded measures of relief. From the period of the expectoration of these substances, accompanied as they were with fits of dyspnœa, which often threatened the extinction of life, the patient's strength rapidly declined, so much so as to render it necessary to suspend all lowering remedies, and even to sustain the action of the heart by cordials. The sesqui-carbonate of ammonia therefore was freely given, and Barclay's porter to the extent of a pint or more daily.

The symptoms still continuing I was again consulted, and on the 5th of July determined on putting him under a gentle course of mercury, yet so as to introduce it rapidly into the system, by combining mercurial frictions with the grey powder given internally. He took two grains of hydrargyrum cum cretâ and one grain of ipecacuanha every fourth hour, and rubbed in a drachm of the strong mercurial ointment night and morning. The mouth was soon affected; and as soon as the specific action of the mercury was apparent there was a sensible diminution of the expectoration, both in quantity and consistency, the patient, for the first time, expressing himself much relieved. Nevertheless, about a fortnight afterwards, another cast of the bronchial tubes was expectorated, with smaller flakes at intervals afterwards.

Towards the close of July he visited me again, considerably improved in strength. More air entered the lower portion of the right lung than formerly; but the respiratory murmur was far from perfect, either there or in the summit of the left lung. The pulse, which throughout has ranged from 100 to 120, was still quick and irritable. There was difficulty in assuming the recumbent position, which was even sometimes impossible. The feet and ancles were frequently a little swollen, although there was a pretty copious flow of urine. A dirty coating of fur loaded the tongue throughout the disease. He now expressed himself cheerfully as feeling much better on the whole; but complains still of a sense of tightness across the front of the chest. I recommended the resumption of mercury, both by the mouth and by inunction, but not quite so actively as before, with blisters and rubefacients to the chest, also a mild expectorant and dieuretic medicine. The patient has just again visited me, on Tuesday, August 6th. His looks are greatly improved; the pulse has fallen to nearly 80, and lost its thrill; the cough has declined very much, and the expectoration nearly ceased.

There is no dulness or percussion, and the air enters the lungs nearly alike everywhere. The only peculiarity about the breathing is a little hoarseness, which seems confined to the larynx. I advised a little longer persistence in the use of the remedies. And here I beg leave cordially to thank Mr. Raines for some very fine specimens of the expectorated casts of the bronchia, as well as for his valuable notes of the case.

The above interesting case seems to warrant a few additional comments.

1. This disease has been almost invariably mentioned by our best writers, Laennec, Stokes, Copland, and others, as occurring during a chronic bronchitis; and Dr. Mason Good calls it bronch-lemmitis chronica. It seems allied in character to the diptheritis of Bretonneau and to the secondary croup of M. Louis, eight cases of which the latter describes as occurring in low states of the system, and in only one of which this plastic production was confined to the wind-pipe, for in all the others the exudation of lymph formed first in the pharynx and extended from thence to the wind-pipe. The opinion, however, that such a production is restricted to low states of the system, and to chronic forms of inflammation, is successfully refuted by some "Observations on Plastic Bronchitis," by Dr. Robert Cane, in the *Dublin Medical Journal*, vol. xvii., p. 116. He there relates an extremely interesting case of this disease, which occurred during an attack, or immediately on the subsidence, of acute pneumonia, the one running into the other. He remarks, however, that though the attack was one of acute inflammation, which required *venesectio ad deliquim*, cupping, leeching, and tartar emetic, yet "it occurred in one of those remarkable lymphatic habits, which would appear to bear out the curious theories of Bretonneau and Graves, regarding the reproductive powers of white-blood animals." My patient, too, was of strumous and lymphatic habit; and the vital powers may be presumed to have been weakened by his previous intemperate habits. It is remarked by Dr. Stokes that "this semi-plastic expectoration apparently indicates a lymphatic constitution of the lung;"* that in croup "the plastic inflammation may be considered as in some way connected with that lower development which

* Stokes on "Diseases of the Chest," p. 64.

precedes the period of puberty;"* and that, as an illustration of the doctrine, that of the different solids the white tissues are those in which the reproductive power is most commonly seen, "the portion of the respiratory apparatus most liable to croup is that in which cartilage is most predominant."† Still, both in Dr. Cane's case and in croup the inflammation is not chronic but acute, although the one is seen associated with the lymphatic habit, and the other with the lower developments of vital action. But that this plastic disposition may be acquired by mucous membranes generally, under high states of inflammation, is evident no less from the products of acute dysentery than from what occurred to a kangaroo, which died soon after a fire had broken out in its cell, and which was taken by its owner to Sir Astley Cooper to be examined. He states in his "Lecture on Adhesive Inflammation," that he found the bladder much distended with urine, and the urethra *blocked up by a plug of lymph.* The inflammation had arisen from the fire of the straw, and was so intense as to go into the adhesive process. Thus the prevailing opinion of the best writers on plastic bronchitis, that it usually accompanies chronic states of disease, may be consistently held with the belief that those plastic formations are sometimes associated with acute inflammation of mucous membranes.

2. There is reason to apprehend that the case which I have described commenced either as pneumonia or severe general bronchitis, if we couple the history of its first stage, so far as we can learn it, with the purulent expectoration in a subsequent stage, which looked very much like the product of an abscess of the lung. Or if that supposition be untenable, still we know that muco-puriform expectoration is more commonly met with in the second stage of acute than in chronic bronchitis. In short, there is much probability in the conjecture that this formidable disease resulted from an early treatment, in which the antiphlogistic measures had not been pursued to the complete extinction of the inflammation. Dr. Stokes observes, that in cases of intense general bronchitis thus mismanaged in the beginning, "the patients have a long and dangerous struggle, with alternations of inflammatory fever and a collapsed state; with *viscid expectoration* at one time and profuse muco-purulent discharges at another; and with the stethoscopic

* Stokes on "Diseases of the Chest," p. 224. † Ibid, p. 211

sight of a state of lung not far removed from the third stage of pneumonia."* There is this difference between such cases and the one I have described, that "the viscid expectoration" spoken of by Dr. Stokes went, in my case, to the length of producing lymph-like casts of the bronchial tubes.

3. The last observation I shall make is, that mercury seems to be the remedy on which the greatest reliance ought to be placed in curing the disease. It will be seen, that I made no decided impression on the *formative inflammation* either by antimony, ipecacuanha, local bleeding, or blisters; but that the moment the mouth was made sore by mercury a great remission of the symptoms followed. I was led to its adoption by reasoning from analogy, and was not then aware that others had arrived, by the same train of thought, at precisely the same conclusion. Thus Dr. Cane says, that while in his case the disease progressed in spite of the antimonial treatment, it yielded at once to the influence of mercury; and Dr. Corrigan, in a letter to Dr. Cane, which is subjoined to his communication, says, that in a case of the same disease, which occurred to him, the plastic secretion ceased as soon as the gums became sore. Dr. Cane's was the *acute* form of the disease, Dr. Corrigan's the *chronic*.

P.S. Convalescence was established on the 6th of August, as stated above. The patient, however, imprudently exposed himself during a fit of cold and wet weather in September, and had a serious relapse. He visited me once more with a recurrence of severe dyspnœa and cough, for which I recommended the treatment which had before relieved him. I never saw him again; nor did he call in Mr. Raines, of Newport. He died in the early part of October. "I regret to say," writes Mr. Raines, Oct. 15, 1850, "that a *post-mortem* was not allowed; and his grave has been strictly watched since his interment."

* Stokes on "Diseases of the Chest," p. 65.

ON THE ACTION OF THE MUSCULAR COAT OF THE BRONCHIAL TUBES IN RESPIRATION, AND ON THE EXCITING CAUSE OF INSPIRATION AND OF EXPIRATION.

BY C. RADCLYFFE HALL, M.D., TORQUAY,

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The office which the muscular coat of the bronchial tubes fulfils in respiration is not at present decided. There is little doubt that it tends to prevent over-dilatation of the tubes by reacting against any undue pressure on the part of the air they contain, precisely as the muscular coat of an artery reacts against the blood-wave when forcibly propelled. We may admit also that it reacts partially and spasmodically for the removal of irritating matter from any part of the tubes, as in bronchial cough. But has it, as its discoverer, Reisseisen, considered, any regular and rhythmical action in the movements of the lungs during respiration? Does it relax with each inspiration, and contract with each expiration? Such an opinion is discountenanced by the latest writers on physiology.* To attempt to show that it is not without arguments in its favour is the object of the present communication.

It is observed by Müller, that if the muscular coat of the bronchial tubes acted rhythmically in respiration, it would have to be under the influence of the will, which is not the case; and, moreover, that the purposes supposed to be fulfilled by such rhythmical contraction would be answered equally well by elasticity. Dr. Carpenter remarks, that "it can scarcely be imagined that the bronchial tubes should, by any power of their own, contract and

* Müller, Dr. Carpenter, Dr. John Reid, Dr. Kirkes.

dilate uniformly with the contraction and expansion of the chest, unless their muscles were equally subject with those of the thorax to the influence of the nervous system, which all experiments concur in showing not to be the case."* It is urged, again, that the only contraction to be seen in experimenting on the bronchial tubes is a tonic, regular contraction, which lasts for some time. "The muscular fibres of the bronchial tubes," said Dr. John Reid, "are endowed with that kind of contractility termed *simple contractility*, which manifests itself by more slow and prolonged contractions and relaxations than that of the voluntary muscles and the heart."†

I have, then, to show,—firstly, that it is not necessary that the bronchial muscular coat should be directly under the control of the will for the purpose of taking a regular part in the act of expiration; secondly, that elasticity would not answer the purpose here fulfilled by muscular contractility; thirdly, that it is not proved that the fibres of the bronchial muscular coat are incapable of the alternating form of contraction, *i.e.*, of quick contraction and quick relaxation; fourthly, that the bronchial muscular coat is under the influence of the nerves to an adequate extent.

1. Müller observes, "The glottis is dilated during inspiration, and contracted during expiration. The bronchial tubes are also dilated during inspiration, and contracted during expiration;"‡ and yet immediately afterwards he states, "it is probable that the bronchial tubes and trachea do not contract and dilate rhythmically during the movements of respiration. Had they this power it would be quite an isolated fact; for although the hepatic duct presents rhythmic contractions, they are quite independent of the will, while, if the bronchi contracted and dilated synchronously with the other respiratory movements, their action, like that of the other parts engaged in respiration, must also be subject to the will, and it is highly improbable that the branches of the efferent tube of an internal viscus would be thus under the influence of the will."§ To this we may reply, that the diaphragm, and other respiratory muscles, present rhythmic contractions, which are not "quite independent of the will;" the heart, rhythmic contractions

* "Principles of Human Physiology," 2nd edition, p. 456.

† Art. Respiration, "Cylopædia of Anatomy and Physiology."

‡ "Physiology," by Baly, vol. i., p. 345. § Ibid, p. 347.

which are quite independent of the will, and therefore that the more or less subordination to the will cannot be the condition on which rhythmic action depends. Moreover, the trachea and bronchi are as much afferent as efferent ducts, and are employed with a constancy and a regularity which distinguish them from any other visceral tubes. It is probable that the muscles of the glottis are only indirectly under the control of the will, and *their* alternating action in respiratory and vocal efforts is admitted. To this extent the muscular fibres of the trachea also are certainly controlled by the will in the production of high vocal notes, and in voluntary coughing. Many involuntary muscles are indirectly influenced by the will through the medium of voluntary muscles. It is not necessary for the tracheal or bronchial muscles to be controlled by the will in any other way than this. By willing to fill the tubes with air until their fibres are on the stretch, or by drawing in particles which irritate the lining membrane, we can at pleasure excite their contraction. By suspending our breath after a moderate expiration we can probably for a short time at pleasure suspend their action.

2. Elasticity opposes any change from its condition when unexcited. It recoils equally from a maximum and from a minimum size. The lessening of the bronchial tubes below their medium size is as much opposed by the elasticity of their walls, as is their dilatation above it. Elasticity tends to maintain their medium calibre, but not either to increase or to lessen this. If, therefore, expiration be at all expedited by lessening of the bore of its tubes, as it undoubtedly must be, something more than mere elasticity is required. In viewing elasticity as equally opposing undue dilatation and undue diminution of the air passages, and as being inoperative so long as the tubes remain of their medium size, we refer to the elasticity of the *walls of the bronchial tubes only,* and to this acting towards or from the centre as regards the tube. Like arteries, the bronchial tubes during health are always kept on the stretch in their length, whatever the amount of expansion or contraction of the lung; and the elasticity of the general parenchyma is never allowed to reduce the lung to the size to which it contracts it on opening the thorax after death. After the fullest possible expiration the general elasticity would reduce the lung still more were it not opposed. Under all circumstances, therefore,

the general elasticity of the lungs, and the *longitudinal* elasticity of the tubes, oppose inspiration and favour expiration. But the bronchial tubes, though on the stretch in the longitudinal direction, are not so in their transverse diameter. The elasticity of their walls cannot lessen the calibre of the tubes any more than it can increase it. What there is of concentric elasticity in the walls of the bronchial tubes is opposed equally to a full expiration and to a full inspiration. In this mode of acting the bronchial tubes precisely resemble arteries. On exposing a small artery, it will contract to half its natural size, in virtue of its muscular coat. It could not do this by its elasticity solely.

The *longitudinal* elasticity of the bronchial tubes can assist expiration merely by drawing the air-cells towards the larger tubes, by the mutual compression of the air-cells which this entails, and by maintaining the internal surface of the tubes smooth and free; not by any such tightening of the circumference of each tube as will diminish its calibre. Yet, to render the expulsion of the breath complete and equable from every portion of lung at the same time, this latter action of uniform lessening of the bore of the tubes is what is chiefly required. Every one has noticed how much more readily an empty sponge is made to fill itself with water than a wet one to empty itself, in consequence of the difficulty of compressing at the same moment every individual portion of it. A like compression of every individual portion of the lung is required for perfect and full expiration. And here the compressing force is placed within the sponge, and lines all its tubes, in the form of a muscular coat.

The structure of the bronchial tubes teaches so much. It is true that the larger bronchi have plates of cartilage, the elasticity of which operates in the transverse direction of the tube; but these are so far from being always kept on the stretch, like the longitudinal elastic fibres, that their principal use is to maintain an open condition of the tubes under all circumstances, by resisting alike concentric and eccentric force. Nor would any considerable lessening of the larger tubes assist expiration. Unless, indeed, it occurred subsequently to progressive lessening of the smaller and more peripheral tubes, it would obstruct the egress of air from the air-cells. If muscular contractility be the agent for lessening the tubes, we find a correspondence with the requirement in the greater

development of the bronchial muscular coat in the smaller tubes; but if elasticity be the agent, this correspondence is wanting; elastic tissues exist in largest proportion in the larger tubes. In the larger tubes we find plates of cartilage, and longitudinal elastic fibres thickly and closely packed. Between these, and separating them, is placed a thin layer of unstriped muscular fibres, which, as they are not firmly attached to the plates of cartilage, can have but little influence over them; and next to the longitudinal fibres, the mucous membrane. In the smaller tubes the cartilages no longer exist; the longitudinal elastic fibres are all placed lengthwise, never across the tube; they branch at their extremities, and intertwine to an extent sufficient to ensure their keeping together, but not sufficient to enable them to either lessen or enlarge the tube in the wall of which they are situated. The circular muscular fibres form a thicker and stronger layer than in the large tubes, external to and surrounding the longitudinal elastic bands. Arrived at the commencement of a vestibular passage, or passage of entrance to several air-cells, the muscular coat ceases abruptly, whilst the longitudinal elastic fibres spread out from under it, and stretching in curved loops over each bunch of air-cells, form the frame-work upon which the thin basement membrane, with its delicate pavement epithelium, is spread to constitute the wall of an air-cell. It results from this arrangement that the openings of the air-cells can never become closed by any action of the muscular coat. Had the muscular fibres been the most internal, their energetic contraction might have closed up (like a sphincter) the door of the vestibule, and instead of dyspnœa, a fit of asthma would have caused asphyxia. As it is, the effect of the contraction of the circular muscular fibres is to press upon the longitudinal elastic bands; these, being always on the stretch, by opposing the pressure, render it uniform and equal throughout the tube; and by their expanding to embrace the air-cells at the point where the termination of the muscular coat leaves a ring of muscle with a free margin, convey the muscular compression on to the walls of the cells, and effectually prevent any ring-like constriction. Thus the channel of the tubes is kept smooth and free, and the openings into the air-cells patent, under every degree of expansion and contraction of the lung.*

* Did space permit, it would be easy to show the bearing which these considerations have on the mechanism of the production of emphysema.

We may conclude that elasticity alone is inoperative in reducing the bore of the air-passages to anything less than its medium condition; that no especial elastic tissue is so arranged as to answer such a purpose; that muscular fibre is so arranged as to answer precisely this purpose, and no other.

3. To ascertain the fact, whether the alternating form of contraction could be excited artificially in the muscular coat of the bronchial tubes or not, the following experiments were made.

Experiment 1.—The trachea and the right vagus nerve were laid bare in a full-grown rabbit. Both needles of an electro-magnetic machine, when applied to the front of the wind-pipe, occasioned general convulsive movements of the body, and spasmodic choking and gasping. Both needles applied to the trunk of the vagus caused similar effects to a still greater degree, shrieking and great pain. The heart beat violently. So far the electricity had evidently been conducted to other tissues by the moist and warm surfaces to which the needles were applied. These effects having subsided, the trachea was divided, and a flexible tube inserted into its lower portion. By directing the free end of this tube against the flame of a spirit lamp, the number, force, and length of the expirations could be readily observed. Galvanism to the vagus nerve quickened respiration, and rendered it tumultuous, disordering the action of the thoracic muscles. The number of expirations was counted for periods of ten seconds. Without galvanism, the expirations were now at the rate of 150 per minute. The right vagus was next isolated over a smooth slip of dry wood, and two slender needles stuck through the nerve into the wood, but not through it, so as to place the intervening portion of nerve in an electric circuit, without the electricity being directly conducted to other animal textures besides the nerve. The nerve was then divided above the wood, near to the base of the skull, so as to prevent any reflex excitement through the root of the vagus. No alteration in the respirations immediately followed this division of one vagus. The galvanic poles were now applied to the needles. The expirations instantly rose to 171, and became more forcible. Without galvanism, the expirations then fell to 72. The other vagus (the left) was next divided in the neck, both nerves being now separated from the brain. With galvanism applied as before, the expirations were at first short, quick, and 138; they then became slower and more

lengthened. In a few minutes they were, without galvanism, 42; with galvanism, 72. The most marked effect of the galvanism upon the expiration, now that this was slower, consisted in the more prolonged, continuous, and forcible expulsion of the air.

The thorax was now opened on the right side, so as to expose the right lung and the right side of the heart. The expirations without galvanism were, 48; with galvanism to the left vagus, 54. No movement whatever could be excited in the exposed right lung, which of course was collapsed, either by galvanism to the right vagus or to the lung itself. The heart ceased to manifest any increase of action from galvanising the nerves in the neck, but contracted with increased vigour and frequency on galvanising the ventricles. The opposite side of the thorax was now opened. Of course respiration instantly ceased, and could not be re-excited by galvanising one vagus, both vagi together, lungs by themselves, or lungs and vagi. No effect now followed the application of galvanism to the bronchial tubes, either whilst the lungs were warm and *in situ*, or after their removal from the chest.

Experiment 2.—The trachea and left vagus were laid bare in a large fowl. Expirations were now 48. On applying galvanism, as in the preceding experiment, to the trachea, vigorous convulsive movements of the whole body, and rapid quivering elevations and depressions of the wind-pipe ensued; so rapid that it could not be ascertained satisfactorily whether the individual rings of the trachea were approximated to each other or not. The trachea was then cut through, a tube inserted, and galvanism applied to the lower portion. This affected equally the upper and the lower segment of the wind-pipe, proving that the electricity was conducted by the warm, moist muscles on which both portions of wind-pipe rested. The left vagus was now isolated over a slip of wood. Expirations without galvanism, 48; with galvanism to the nerve, 72. With galvanism to the trachea only, expirations 54, and general struggling. With galvanism applied again to the left vagus, expirations 60; without galvanism, 48.

The vagus was not cut through in this experiment.

After death, galvanism was immediately applied to the heart, stomach, trachea, bronchi, and substance of lung, but produced no effect.

Experiment 3.—A large rat was held under water. It was 80 seconds in drowning. The rat was taken out of the water, and its trachea was divided. A tube was fastened into the lower portion of the trachea, and its orifice was held under water at some depth. On opening the front of the chest, the pressure of the water in the tube prevented the egress of the air from the lungs, which therefore did not collapse. Galvanism was then applied to both vagi at once, and caused immediate, sudden bubbling of air from the mouth of the tube under water. After this, no effect. The tube was then emptied of water, and the lungs were fully inflated through it, and the tube again submerged. According as the depth of the tube in the water permitted the resiliency of the lungs to operate or not, the air bubbled out spontaneously, but no further action could be elicited by galvanism applied to the vagi, to the trachea, or to the substance of the lungs.

Experiment 4.—Both lungs were exposed in a large frog. They rose and fell with each pulsation of the heart, but had no other movement. Mechanical irritation of their surface induced no contraction in the wall of their transparent honey-combed lung-sacs. When artificially over-inflated through the glottis, the lungs would return to their medium size, expelling the superabundant air, but this resulted from elastic recoil merely. Mechanical irritation of the vagi had no perceptible effect.

Examined with a half-inch power, whilst the animal was alive, the blood-globules were seen to stream through the vessels of the diaphanous walls of the lungs with great but very irregular rapidity. When the lung recoiled after its pulsational elevation, a momentary check occurred in the race of the blood-globules. In the larger vessels, this check caused the globules to oscillate; but in the capillaries it occasioned merely a more tardy rate of travel. If, however, the capillaries farther on had become impacted with globules, so as to become impervious, then the nearer capillaries leading to them also presented oscillation of the blood-globules. So long, therefore, as the whole net of capillaries is free, the course of the blood through them is regular and uniform in passing on, but not quite uniform as to rate of travel, being quickened by each contraction of the heart; whereas in the vessels larger than the capillaries the blood is not uniform and regular in passing on, but

gushes in a to-and-fro tidal stream, advancing more than it recedes with each systole of the heart. To equalize the stream and convert an intermittent into a steady and constant pressure, both the muscular and elastic properties of the coats of the arteries are doubtless called into action. This observation appears to answer in the negative a query, propounded by Dr. Charles Bell, viz., whether the actions of the capillaries in general do not receive a constantly repeated stimulus from the alternate flux and reflux of the blood-wave. It also demonstrates that the capillaries will be always equally full in a state of health, provided the circulation through them be unobstructed; but that their fulness will instantly become augmented provided any obstruction occur.

The check in the blood-wave in the smaller vessels (not capillaries) immediately preceded the pulsation of the heart, and accompanied the slight falling of the lung from its pulsational elevation. In point of time, it occupied about one part out of five. In the capillaries, the blood-globules were noticed to pass across the field in single file, each globule becoming elongated and somewhat dumb-bell shaped as it passed through a small capillary, and resuming its ovoid globular outline on entering a larger vessel. The walls of these small capillaries could not be seen at the focus employed.

The observation was continued for three hours. As the lung became dry from exposure, and the heart's contractions more languid, the lung appeared more and more congested to the naked eye. Under the microscope this congestion was found to consist in mere impaction of globules in the vessels, not in extravasation of globules or of *liquor sanguinis*, so far as could be made out. It does not follow that such would be the case in a similar state of congestion of the lungs in the living body, warm and moist.

Experiment 5.—On exposing the lungs in a frog, they burst out and expanded by successive deglutitions of air to their maximum size. No appearance of anything like muscular reaction of the lung followed each gulp of air. On the jaws being held separate, the frog made a twisting movement, and the lungs immediately collapsed. As soon as the lungs had again become filled with air, galvanism was applied to both lungs at once. It occasioned general struggling and instantaneous emptying of the lung-sacs. Allowed

to become filled with air again, galvanism was applied to one of the lungs only: no effect.

Experiment 6.—Three frogs. It was tried to induce collapse of the lungs by galvanism. This effect always ensued when both lungs were galvanised together, so that the current of electricity passed across the body of the frog, and excited convulsive movements, but never so long as the galvanism was restricted to the walls of one lung. Galvanising the vagi had no perceptible effect. As in the preceding experiment, the lungs rose and fell with each pulsation of the heart. In one particular a correspondence was noted between the state of the circulation and the amount of pulsational elevation. The circulation was freest, and the rise of lung greatest, when the distension of the lung with air was to a medium extent. If the lungs were distended to the utmost, pulsational elevation was scarcely noticeable. If almost empty, the same. Under the microscope, the difference in rate of travel and in freedom of passage of the blood-globules, in accordance with the amount of distension of the lung with air, was equally well marked. When the lung was greatly distended the circulation through the capillaries was almost at a stand. When the lung was almost empty many capillaries were obstructed by the pressure of adjoining portions of the collapsing walls, and the circulation in others was more tardy. But when the lung was moderately full of air, the circulation was most free, most equal, and most rapid. It could not be made out whether the rate of capillary circulation was influenced by the purity of the air contained in the lung, that is, whether circulation was faster immediately after the ingestion of fresh air than after the air has remained in the lung-sac for some time, or the reverse.

It will be observed, in passing, that we have here by analogy a demonstration to the eye, of what experience has long since taught, that moderate exercise of the lungs promotes freedom of circulation through their blood-vessels, whilst inactivity of the lungs, and over-distension of them with air, equally oppose freedom of circulation, and thereby favour the production of congestion, or the augmentation of any which may already exist.

Experiment 7.—Both lung-sacs were removed from a large frog.

The animal lived for two hours, making frequent inspiration-like movements of deglutition.

Experiment 8.—Galvanism was applied to the exposed surface of the heart in three frogs. At first the pulsations were increased in frequency, maintaining their proper rhythm. Presently, the ventricles contracted slowly, until they were squeezed tight and firm, without any attempt at dilatation interrupting the contraction. They remained in this state for from 8 to 15 minutes, the galvanism being taken away. They then gradually relaxed, admitted blood from the auricles, and proceeded to pulsate rhythmically again. Galvanism, again applied, induced the tonic contraction as before. In two of the frogs this was done twice, in the third three times, after which the heart remained contracted and motionless, and refused any further manifestation of activity.

In this artificially induced persistent spasm of the heart in the frog, have we not the type of the cause of death in angina pectoris, and perhaps also in certain cases of suddenly fatal epilepsy?

We learn from these experiments, that the expirations can be notably quickened and rendered more forcible in birds and mammalia by galvanising the vagi; that in the frog, galvanism applied to the lung alone has no effect, but that if conducted to the spinal cord, so as to excite general movements and opening of the glottis, it then indirectly affects the lungs by opening their entrance-passage, and allowing their elasticity to expel the air they contain; that experiment thus confirms anatomical examination in deciding that there is no muscular tissue in the lungs of Batrachian reptiles; and that a muscle whose normal duty it is to contract in the alternating manner, viz., the heart, may be made, by over-stimulation, to assume the persistent tonic form of contraction.

The capability of the bronchial muscular coat to undergo the alternating contraction, which it must if it alternately contract and relax with every expiration and inspiration, is not demonstrated to the eye, but it seems to be all but proved inferentially. The general muscles of respiration were excited by galvanism applied to the vagi, even when these were prevented by division from acting as excitors through the medulla oblongata, and when precaution was taken to prevent the electricity from being conducted away from the nerves. We must assume that the galvanised vagi acted

centrifugally, and produced an impression of some kind on the terminations of the cerebro-spinal nerves distributed in the lungs, and induced through them excito-motory action of the respiratory muscles at large. What proof, then, do the experiments 1 and 2 furnish that the bronchial muscular coat was stimulated at all, since the excitement of the general respiratory muscles is enough to account for the increased frequency of the respirations? It will not, however, explain why the effect should be manifested chiefly by *ex*piration, rather than by *in*spiration. Under ordinary circumstances, any interference with breathing is first and principally shown by the inspiratory act, whilst in these experiments it was noticeably the expiratory part of respiration that was made more forcible by galvanising the vagi. I infer that the bronchial muscular coat was stimulated to contract, and that it did so rhythmically after its normal fashion, and that it was in consequence of the increased rapidity of its contractions thus induced that the expirations were increased in force, suddenness, and frequency. If it be objected that the bronchial muscular coat has never been seen to present any other than tonic contraction when exposed to view, we may reply that the conditions are then so opposite to the natural ones under which breathing is performed, that we have no right to decide what the muscle *cannot* do during health from what it *will* do when exposed to sight in a cooled and collapsed lung. In experiments on the stomach, Longet proved that the state of fulness or emptiness of the organ modifies to the greatest extent the kind and degree of movement excited by stimulating the par vagum. So may the emptiness of the bronchial tubes, and the removal of the general elasticity which is always operating in the normal condition, prevent the bronchial muscular coat from acting in its normal manner. In the preceding experiments, left undisturbed and unexposed, and in every respect, excepting in the application of a stimulus to its nerves, placed under its natural conditions, we have reason to expect that the bronchial muscular coat, if excited at all, would show that excitement by an increase of its normal mode of acting. Dr. C. B. Williams and other observers have established the fact of the contractility of the bronchial tubes, and Volkmann has found that this contractility is excited by galvanising the vagus. If, then, contraction were excited in the above experiments, it could not have been the tonic form of contraction. Nothing but alternate

contraction and relaxation will account for the augmented force and frequency of the expirations. Nor is the opposite view strengthened by the occurrence of tonic contraction (*i.e.*, spasm) of the bronchial tubes in nervous asthma. Here, the exciting cause is so intense that it may affect the bronchial muscular coat precisely as we have seen that over-galvanising will affect the heart in the frog, *i.e.*, it may induce spasm in a muscle which, under gentler and more normal excitement, would perhaps (like the heart) present the alternating kind of contraction. At all events, we can no more suppose that so inconvenient and distressing a condition as that of asthma represents the ordinary and healthy mode of contraction of the bronchial muscular coat, than we can infer the ordinary mode of action of voluntary muscles from the tonic rigidity of tetanus, or that of the heart from the tonic spasm of angina pectoris. And, admitting that spasmodic asthma furnishes an illustration of tonic contraction of the bronchial tubes, have we not an equally strong pathological illustration of alternating contraction, or clonic spasm, in the repeated convulsive expirations of whooping cough, and in certain varieties of hysterical cough?

4. The last objection, viz., that the bronchial muscular coat is not sufficiently under the influence of the nerves of respiration, provided my interpretation of the experiments adduced be correct, is no longer tenable.

Having endeavoured to dispose of the objections advanced against the theory of Reisseissen, I proceed to consider what may be stated in its support.

A strong argument by analogy is deducible from the fish, in which the normal movements of the respiratory organs may be watched. Respiration in the fish consists in the deglutition of water, as in the batrachian it consists in the deglutition of air. There is, therefore, no distinct inspiration and expiration. Still the process is divided into a stage of ingress, with open mouth and closed gills, and one of egress, with closed mouth and open gills; and the two acts are performed in rhythmical order, like the inspiration and expiration of lung animals. The hyoid apparatus acts as a piston to the common cavity of the mouth, pharynx, and gills. By its retraction when the gill outlet is shut, water is sucked through the open mouth. The muscles which retract the hyoid arch relaxing, the mouth is closed, the arch advances, the opercular covers press down against

the expanded gills, the branchiostegal valvular folds which closed the gill outlet are tucked up, and the water is driven out. Between the two rows of fringe-like processes which each branchial arch usually presents, a plane of well-developed muscular fibres exists. Judging from its anatomical connexions, this interbranchial muscle will move the two rows of gill processes upon each other, approximate them when separated, and compress the gill processes altogether against the inner boundary of the branchial chamber. Supposing that such muscular action were to operate during the ingress of the water, it would prevent the free access of the fluid to the surface of the vascular branchial fringes, and defeat the object intended. But supposing the gill processes to be separated to receive the influx of water, the interbranchial muscles being relaxed, the contraction of these muscles during the subsequent stage of egress of the water will expel the fluid from between the branchial fringes, and thus materially assist in emptying the recesses of the gill-chamber, and also by squeezing the water through the vascular fringes, bring the blood of the fish into closest contact with the aërating medium. May we not fairly assume that the interbranchial muscle of the fish corresponds to the bronchial muscle of the mammal; that the act of expelling the water from the gills corresponds to the act of expiration; and that the interbranchial muscle operates as an expiratory agent? It may be that there is a further analogy. Any particles of food or of other foreign matter which, having escaped the sieve-like sensitive valves placed at the pharyngeal openings of the gills, may have insinuated themselves between the vascular membranes of the branchial processes, will here excite irritation and excito-motory contraction of the interbranchial muscles to an extent sufficient to produce the ejection of the irritating particles into the sphere of the large current of water passing through the gills. If so, the process of expulsion will be the analogue of the cough of mammalia.—The expansion and closure of the gills and gill-fringes may be readily observed in the common gold-fish in a globe of water.

Granting the analogy, let us trace its consequences. The interbranchial muscle must ordinarily act in unison with the other muscles of expiration. Were it to hold the gill processes in close approximation during the act of inspiration,—so to term the stage of ingress of water,—it would prevent the application of the water

which is to purify the blood in the membrane which it bathes; on the other hand, were it to fail to contract after the water between the separated gill processes had become depraved by fulfilling its office, it would prevent a sufficient change of water at the next inspiration, and would perhaps allow the closing gill-covers to press together portions of the bronchial processes irregularly and unequally. Again, we cannot suppose the interbranchial muscles to exist merely for an occasional purpose but rarely required, and not to fulfil a constant purpose, for which their arrangement admirably adapts them. I assume, therefore, that they act rhythmically with every closure of the gill-covers, *i.e.*, with every act of expiration. In what does this rhythmical action consist? Merely in their fibres contracting every time they are stretched, ceasing their contraction as soon as they have effected it. And if we deny this we fall into a conclusion far more improbable, viz., that by elasticity and the action of the hyoid and opercular muscles, the gill processes are alternately opened and shut, separated and approximated, and yet that an extensive layer of muscle placed between each row of branchial fringes, during all this constantly recurring movement of the parts to which it is attached, remains passive. So, in mammalia, it is admitted that during every inspiration the glottis, trachea, and bronchial tubes dilate and widen, and during expiration contract and lessen. Unless, then, the tracheal and bronchial muscles do rhythmically contract with each expiration, and relax with each inspiration, we are forced to conclude that they are alike unaffected by stretching and shortening of their fibres; a conclusion opposed to the ascertaincd attributes of both striped and smooth muscular fibres.

The rhythmical contraction of the bronchial tubes is conformable with what we know of the physiology of respiration in general. How is it excited, directed, and controlled? The rhythm of the bronchial tubes must coincide with that of the respiratory muscles at large. We cannot voluntarily alter the rhythm of respiration, without wilfully affecting the external conditions of respiration, either by modifying the action of the muscles, the quantity and quality of the air, or in some other way the relation of the blood to the lungs. And if these external conditions be altered, respiration is altered, whether we will or not. Hence the rhythm of respiration depends more on external conditions than on the nervous

centre itself. The nervous centre is the governor of the process, but not the cause of it, and in its government it is largely dependent on the conduction of impressions from the acting organs.

We must seek, then, for the exciting causes of the rhythmical action of the respiratory muscles, not in the medulla oblongata, which is merely the controlling power, but in the external conditions which excite in succession the acts of inspiration and expiration. Respiration, as a double excito-motory act, requires an excitor for inspiration, and an excitor for expiration, so arranged that they shall alternate in their application, and consequently in their effect. This constitutes the rhythm. "What," said Dr. John Reid, "are the excitations which lead to the performance of the muscular movements of expiration? Do the same excitations that occasion the muscular movements of inspiration operate in the production of the expiration which immediately follows, so that they are to be considered two stages of the one and same muscular action? These are questions which we are not prepared to answer."* In most works on physiology, the exciting cause of expiration has not been made a subject of consideration, whilst many and various conditions have been assigned as the ordinary exciting cause of inspiration. Of these may be enumerated, the presence of carbonized blood in the vessels of the lungs; of carbonic acid in the air-cells; and of carbonized blood in the capillaries of the system at large, either superadded to one or both of the former conditions, or constituting in itself the exciting cause of the act of inspiration under ordinary circumstances.

Stating them as mere postulates, there are some grounds for considering that the ordinary exciting cause of inspiration is distension of the capillaries of the lungs with carbonized blood; and the exciting cause of expiration, the presence in the air-cells and bronchial tubes of unduly carbonized air.

That distension of the pulmonic capillaries with carbonized blood, and not the presence of carbonic acid in the air-cells, is the ordinary exciting cause of the act of inspiration, is presumable from the following considerations. In the fish, the sensation which excites the taking into the mouth of fresh water cannot depend on the presence of carbonized water in the gill-processes, since the gills have just been emptied of the used water. The presence in

* Loc. citat.

the branchial capillaries of venous blood requiring oxygenation is the only adequate condition we can find. In mammalia, the desire for inspiration immediately succeeds to the expulsion of the impure breath, at the moment when the lungs must contain the smallest proportion of carbonized air. The most urgent distress for fresh air attends disease in man, in which pulmonic engorgement prevents the access of air at all to a great portion of the lungs, or in which a sticky secretion clogs the air-cells and their vestibules. Here the desire for breath is greatest, whilst the amount of foul air in the air-cells, because of the absence of *all* air, is least; but the capillaries are gorged with venous blood, which cannot part with its pulmonic excretion. The presence of unduly carbonized blood in the capillaries of any part of the system, at all events, its presence in the medulla oblongata appears capable of exciting an inspiratory act, independently of the state of the lungs, as in the frog from which the lungs had been removed. If the like condition of the pulmonic capillaries be the ordinary excitor, we have a similarity in the conditions which act as excitors of inspiration in different parts of the system. But what proof have we, that under ordinary circumstances the state of the lungs has anything more to do in exciting the desire for breath, than that of any other part of the body? It would be strange if the instinct which points to the chest as the seat of the earliest feeling of desire for breath were altogether wrong in its indication. By division of one vagus the number of respirations is dropped about one-fourth. By division of both vagi at once the respirations are dropped one-half. I see no other mode of accounting for this than by considering that one great normal source of excitation of inspiration (viz., the lungs,) has had some of the wires of its electric telegraph to its nervous centre cut off, and that it can therefore send only an imperfect message to demand supplies. In this we see an illustration of the law that every reflex act is considerable in proportion to the sum of the excitement set up in the nervous centre, and this usually is in direct proportion to the number of nerve-fibres by which the excitation is conveyed. Cut through half of the excitor nerve-fibres, and other circumstances the same, the excitation is reduced by one-half, and the resulting movements become only half as forcible, or half as frequent. Now, did the lungs only share with the rest of the body in exciting the

sensation of want of breath, division of all their nerves (and the vagi do not constitute half of their nerves), would not produce the full effect which ensues from division of the eighth nerves. Conversely, through what other nerves can we quicken respiration in the same manner that it was quickened by galvanising the vagi in the experiments I have narrated? The vagi are the chief, though not the only excitor nerves proper to the lungs; as their irritation accelerates the frequency of the respirations, and their division greatly retards it, it seems to be proved that the lungs are greatly concerned in setting up the sense of desire for breath.

The following considerations support the opinion that the prcsence of carbonized air in the smaller air-passages and air-cells is the exciting cause of expiration. In the fish, the water is expelled from the gills as soon as it has received the excretion of the branchial membrane, *i.e.*, expiration occurs as soon as the water has become carbonized. In batrachian reptiles the air is expellcd from the pulmonic bags after it has rcmained for an uncertain period undergoing admixture with the pulmonic excretion. In mammals, the desire to expire arises as soon as the fresh air inspired has had time to become depraved. The desire for expiration is intense in direct proportion to the length of time that breathing has been suspended, and consequently in direct proportion to the degree in which the air contained in the lungs has become impure, excepting only when the lungs happened to be contracted below their medium size when the suspcnsion of breathing was commenced. Carbonic acid when inhaled induccs closure of the glottis. It is a fair deduction that it would cause contraction of the tracheal and bronchial muscles if applied in strength to the membrane which covers them. If thc carbonic acid of the breath so affect the bronchial muscular coat, as the contraction of that coat can only participate in the expiratory part of respiration, it follows that the presence of carbonic acid in the air-passages tends to excite one link in the chain of expiratory actions.

Is the effort of the bronchial muscular coat to contract one source of that sense of constriction in the chest which is felt on holding thc breath too long after a full inspiration? If so, the sensation of muscular tension in the air-passages may assist in rendering the desire to expire air from the distended lungs more urgent. But this muscular tension is certainly not the first nor

the chief excitor of the act of expiration. Reptiles expire air without having any muscular texture in the walls of their lungs. Partly from this cause, but chiefly from their being cold-blooded animals, reptiles can hold their breath for a long and uncertain time. Having to remain under water for irregular periods, they would be only incommoded by possessing muscular lungs, which would tend to contract on the contained air as soon as this had become charged with carbonic acid. Mammals, on the other hand, require purer blood, and cannot expel carbonized air from their lungs too rapidly, or replace it too completely. Hence they possess muscular lungs.* When a rat drowns, bubbles of expired breath make their appearance in 30 or 40 seconds, whether the animal struggles or not. When a frog is submerged, bubbles of expired air may not rise for a quarter or half-an-hour, or they may rise immediately, just as the animal struggles or remains quiet. I infer that in the rat, the bronchial muscular coat contracts, and compels some air to escape; but in the frog, the lung-sacs having no muscular fibre to become excited, expel the air only when an accidental opening of the glottis permits its escape.

The non-existence of muscle in the lungs of the batrachian, where respiration is not regularly rhythmical, and its existence in those of mammalia, where respiration is regularly rhythmical, points out that the contraction of the bronchial muscle is at least not opposed to rhythmical action.

It has been ascertained that a stream of carbonic acid checks circulation in the capillaries. If the presence of carbonic acid in the air-passages thus checks circulation in the capillaries of the lungs, it of course tends to produce the condition of vascular fulness, assumed to be the exciting cause of inspiration. In this case the carbonized air will not only excite contraction of the bronchial tubes and other concomitant acts of expiration, but will also favour the occurrence of the next act of inspiration, by inducing the commencement of that fulness of the capillaries which, increasing, excites inspiration. Occasionally, indeed, it would seem as if

* Cetaceans can remain below water for a much longer period than other mammals, and yet possess muscular bronchi, but their normal frequency of respiration (in the whale) is not quicker than 5 or 6 per minute, and there is special provision made in the suproficial position of the larger bronchial tubes, as well as in the extensive retiform blood-sinuses, for preventing distress.

the two excitations were in operation together, and that, either, one prevailed because it became the stronger of the two, or else because volition interfered. Thus, after a moderate expiration, if a man holds his breath as long as possible, the immediate desire will be for inspiring. Here there are carbonized air to excite expiration, and capillary distension to excite inspiration. As the lung is but imperfectly filled, the latter condition predominates in intensity. The bronchial tubes having left off with expiration, are kept below their medium size; their contractility is tired out, and their elasticity tends to enlarge them up to their medium calibre. On every account the tendency is towards inspiration. But let the breath be held after a full inspiration, and the conditions are reversed. The expanded bronchial tubes tend to return by their elasticity down to the medium calibre, their stretched and specifically excited muscular coat tends to contract, the tubes and cells filled with air, which has become impure, occasion intense desire for expiration, and expiration ensues. If the breath be held at a medium amount of expansion of the chest, so that the conditions are evenly balanced, the subsequent act is that of inspiration or of expiration indiscriminately. By an effort of will we may interfere with these tendencies, because the voluntary movements of respiration are stronger than the automatic. By a strong effort, for example, after holding a full, but not the fullest inspiration as long as is comfortable, we may draw in a little more air with momentary relief, but our feelings prove that we are thwarting nature. The automatic arrangements are tending towards expiration, and expiration must follow almost instantly.

Thus, inspiration necessarily leads to the condition which is the exciting cause of expiration; and expiration necessarily leads to that which induces inspiration.

All tubular muscles appear to respond directly, without the necessary intervention of any nervous centre to the mechanical stimulus of distension; and all are paralysed by over-distension. It is doubtful with respect to the bronchial muscular coat, whether any amount of inspiratory force can call forth this characteristic. The inward rush of air finds so ready a diffusion amongst that which fills the air-cells that these more yielding structures are the parts to suffer from excessive force of inspirations, and intervesicular emphysema, not burst, or dilated, or palsied bronchial tubes is the

result. But if the contractility of the tubes be never excited by force of inspiration, the expansion by heat of air shut in by closure of the glottis may increase the tension of the tubes as well as of the air-cells, and this mechanical distension may excite the contractility of the muscular tubes, in addition to the other exciting cause of expiration, viz., the presence of carbonized air. I find, with the spirometer, that a very slow and protracted expiration after a full inspiration does not raise the cylinder so high as a more speedy expiration. In other words, there is more breath left behind in the lungs. Are the bronchial tubes tired of keeping up their contraction until all the reserve air is expelled? Of course, the vascular fulness becoming greater in proportion to the time occupied by the experiment, may render the desire to inspire irresistible before all the reserve air has been expired.

Under whatever circumstances, if mechanical distension of the bronchial tubes do influence their contractility at all, it will always operate on the side of expiration. Still any such influence is quite subordinate to that exercised by the presence in the air-cells of carbonized air.

After a full inspiration, I can hold my breath for a period represented by 4. Here there is the least carbonic acid relatively to the amount of air in the lungs, but the greatest mechanical distension of the air-tubes. After a moderate inspiration, for $1\frac{3}{4}$; after a complete expiration, for only 1. Here is the largest relative amount of carbonic acid, but the least muscular distension —there is rather muscular contraction—of the bronchial tubes. Provided a very full inspiration immediately preceded the last trial, so as to freshen up the residual air in the lungs, the time during which suspension of breath could be maintained was increased one-half. Here the degree of dilatation or of contraction of the bronchial muscular coat was the same as in the third trial, but the purity of breath was greater, and the period of its suspension was consequently greater also.

We must conclude, that although the state of dilatation of the air-passages which immediately precedes the commencement of expiration may, by stimulating the stretched muscular fibres to contract, co-operate as a secondary and subordinate cause of the expiratory act, yet the carbonization of the air in the lungs is the essential and primary exciting cause of expiration, and with the

degree to which the breath has become carbonized the desire to expire air directly corresponds.

The residual air left in the air-cells after a complete expiration is probably always more or less carbonized. It is fit for use when *minus* carbon; unfit when *plus* carbon; but some amount of carbon it must always contain. Consequently, it must either be the condition of *plus* carbon only which excites expiration, or otherwise the exciting cause does not make its impression in the air-cells, but solely in the tubes to which common pure air does reach with every inspiration. The exciting impression is probably made in both places, but the question cannot yet be determined.

Inspiration has many other exciting causes besides the state of fulness of the pulmonic capillaries with venous blood, which is here assigned as its ordinary cause; such are impressions suddenly made on any part of the skin or of the mucous surfaces, acute sensations, and mental emotion. But if the view here espoused be correct, expiration has no other primary exciting cause besides the presence of air in the lungs charged with the pulmonic excretion. A frog, with its lungs removed, makes *in*spiratory efforts of breathing only. When the will does not interfere, the spontaneous effort of breathing made by a person struck, or surprised, is one of inspiration. As inspiration is a necessary preliminary to expiration, —as expiration is necessarily excited by air when inspired and used in the lungs, to render the act of inspiration liable to several different modes of excitation, is indirectly to confer the same privilege on expiration, although the proximate exciting cause of the two acts differs.

It is an advantage resulting from this ready and instinctive excitability of inspiration, that the body is instantly fitted for powerful muscular action by the very stimulus which renders that action necessary. For all active efforts a tolerably full and fixed chest is required as a fulcrum from which the muscles may act. Were the effort instantly excited by sudden sense of danger to be one of expiration, the body would be rendered mechanically as powerless by the emptying of the chest as it often is mentally by fear.

To recapitulate,—There seems reason to admit,

1. That, by their general elasticity, the lungs are always kept on the stretch, and tend to contract to a smaller size than is ever permitted during life. This, under all circumstances, is favourable to expiration.

2. That by the elasticity, which acts transversely in the walls of the air-passages, the tubes are accommodated to the amount of air admitted into, or contained in them; but that, for enlarging the tubes for inspiration, and for lessening the tubes below their medium size for complete expiration, this elasticity is useless.

3. That the muscular contractility of the bronchial tubes, whilst, like the transverse elasticity, it resists over-dilatation during full inspiration, *can* reduce the tubes to less than the medium size, as is required in forced expiration.

4. That, inasmuch as forced expirations always alternate with inspirations, the contraction of the bronchial muscular coat must here be of the alternating kind, and not of the tonic persistent kind noticed in certain experiments.

5. That, if the bronchial muscular coat can thus contract rhythmically in forced expiration, there is no reason for denying that it so acts, to a less extent, in ordinary breathing. Considering, indeed, the constant interruption to quiet breathing in the daily occupations of every man, from exercise of the voluntary muscles generally, and of the voice, from variations of temperature, and from mental causes, it is little probable that any part of the machinery required for forced respiration is quite unemployed during ordinary breathing.

6. That, as far as our knowledge will permit, the objections to such a view have been shown to be without sufficient foundation.

7. That the exciting cause of inspiration in ordinary breathing is fulness of the capillaries of the lungs with carbonised blood, but that there are many other auxiliary and occasional exciting causes of inspiration.

8. That the sole and exclusive exciting cause of expiration is the presence of unduly carbonized air in the lungs.

In conclusion, these views, if correct, are not devoid of practical interest. For an application of a portion of them, I must refer to the ingenious remarks of Dr. C. B. Williams, under the head of "Asthma, Paralytic Dyspnœa, and Dilatation of the Bronchi."*

* "Library of Medicine," vol. iii., from which I must quote the following, as more explicitly disclosing Dr. Williams's own view than any other passage I have met with. "It is probable that the contraction of the circular fibres of the bronchi, excited by a certain degree of foulness of the air that is within them, is an essential part of natural expiration."—p. 90.

The mere existence of the muscular elastic and cartilaginous textures which enter into the structure of the bronchial tubes, will dispose us to admit the influence of Gout and Rheumatism on bronchial affections. And the admission, that the bronchial muscular coat co-operates in every expiration, supplies us with an additional reason, were any wanting, for endeavouring to render bronchitic attacks as short as their naturally tedious course will permit, and for taking every care to prevent relapses in a very relapsing disorder. Seeing that the effect of inflammation is, first to paralyze, then to soften and destroy muscular fibre, and to spoil elastic tissue, the effect of bronchitis in producing defective expiratory power, local dilatations of the bronchial tubes, or vesicular emphysema, is susceptible of explanation on merely mechanical principles. So also may fatty degeneration of any part of the bronchial muscular coat give rise to local dilatation, by furnishing a weak and yielding spot in an elsewhere contracting tube.*

* As Mr. Rainey has proved with respect to fatty degeneration of the walls of the air-cells in (one form of) vesicular emphysema.

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C. R. Bree, Esq., Surgeon.
Spencer Freeman, Esq., Surgeon.

STRADBROKE, Suffolk.

George Mayhew, Esq., Surgeon.

STRATFORD-ON-AVON, Warwickshire.

Thomas Thomson, M.D., Physician to the Infirmary, Stratford.

SUDBURY, Suffolk.

Arthur James Skrimshire, M.D.

SUNBURY, Middlesex.

John Smith Soden, F.R.C.S., late Surgeon to the Bath United Hospital.

SUNDERLAND.

Joseph Brown, M.D., Physician to the Sunderland and Bishop-Wearmouth Infirmary.

SWAFFHAM, Norfolk.

Caleb B. Rose, Esq., Surgeon.

SWANSEA, Glamorganshire.

George Gwynne Bird, M.D., Surgeon to the Infirmary, Swansea.

TAUNTON, Somersetshire.

William Marwood Kelly, M.D.
Francis H. Woodforde, M.D.

THETFORD, Norfolk.

W. H. Bailey, Esq., Surgeon.

THRAPSTONE, Northamptonshire.

John Griffiths Leete, Esq., Surgeon.
Hugh Williams, Esq., Surgeon.

TORQUAY, Devonshire.

John James Field, M.D., Physician to the Torbay Infirmary and Dispensary.
Jonathan Toogood, M.D.
J. Baruch Toogood, Esq., Surgeon to the Torbay Infirmary and Dispensary.
Thomas Hunter, Esq., Surgeon.

TOTNESS, Devonshire.

William Gillard, Esq., Surgeon.

WARMINSTER, Wilts.

George Vicary, Esq., Surgeon.

WARRINGTON, Lancashire.

George Wilmott Hardy, Esq., Surgeon to the Infirmary and Dispensary, Warrington.
John Sharp, Esq., Surgeon to the Lying-in Charity, and Consulting Surgeon to the Dispensary and Infirmary, Warrington.

WELLINGTON, Salop.

Matthew Webb, Esq., Surgeon.

WELLS, Norfolk.

James Young, Esq., Surgeon.

WHALLEY, Lancashire.

Richard Hindle, M.D., Billington Retreat.

WIGAN, Lancashire.

George Daglish, Esq., Surgeon.

WINCHESTER.

Andrew Crawford, M.D., Physician to the Hospital, Winchester.
W. J. Wickham, Esq., Surgeon to the Hospital, Winchester.

WINSLOW, Buckinghamshire.

George Cowley, Esq., Surgeon.

WISBEACH, Cambridgeshire.

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Robert Wales, Esq., Surgeon.

WITHAM, Essex.

T. Tomkin, Esq., Surgeon.

WOODBRIDGE, Suffolk.

Richard Jones, Esq.

WOLVERHAMPTON, Staffordshire.

George Edwards, Esq., Surgeon to the South Staffordshire General Hospital, Wolverhampton.
John Fowke, Esq., Surgeon to the General Dispensary, Wolverhampton.

WORCESTER.

Henry Douglas Carden, Esq., Surgeon to the Infirmary, Worcester.
Jonas Malden, M.D., Senior Physician to the Infirmary, Worcester.
James Nash, M.D., Physician to the Infirmary, Worcester.
Matthew Pierpoint, Esq., Surgeon to the Infirmary, Worcester.
James P. Sheppard, Esq., Senior Surgeon to the Infirmary, Worcester.
J. H. Walsh, Esq., Surgeon to the Ophthalmic Institution, Worcester.
P. H. Williams, M.D., Physician to the Dispensary, Worcester.
Thos. Stephenson, Esq., Consulting Surgeon to the Ophthalmic Institution, Worcester.
Richard Hill, Esq., Surgeon, Worcester.

WREXHAM, Denbighshire.

Thomas Taylor Griffith, Esq., F.R.C.S., Surgeon to the Infirmary, Wrexham.
Edward Williams, Esq., M.D., Wrexham.

YORK.

James Allen, Esq., Surgeon, Lecturer on Midwifery in the Medical School, York.
H. S. Belcombe, M.D., Senior Physician to the County Hospital, and Physician to the Retreat, York.
Benjamin Dodsworth, Esq., Surgeon to the Dispensary, York.
Richard Hey, Esq., Surgeon to the County Hospital, York.
W. D. Husband, Esq., Surgeon, Lecturer on Forensic Medicine in the Medical School, York.
Thomas Simpson, M.D., Physician to the County Hospital, Asylum, and Dispensary, and Lecturer on Medicine in the Medical School, York.
Caleb Williams, Esq., Surgeon to the Retreat, and Lecturer on Materia Medica in the Medical School, York.

NAMES OF PRESIDENTS.

Edward Johnstone, M.D., Birmingham	1832–33.
Andrew Carrick, M.D., Clifton	1833–34.
John Johnstone, M.D., F.R.S., Birmingham	1834–35.
J. Kidd, M.D., F.R.S., Oxford	1835–36.
Edward Holme, M.D., F.L.S., Manchester	1836–37.
Henry C. Boisragon, M.D., Cheltenham	1837–38.
Edward Barlow, M.D., Bath	1838–39.
Thomas Jeffreys, M.D., Liverpool	1839-40.
George Steed, M.D., Southampton	1840–41.
George Goldie, M.D., York	1841–42.
John H. James, Esq., Exeter	1842–43.
William Hey, Esq., Leeds	1843–44.
Archibald Robertson, M.D., F.R.S., Northampton	1844–45.
George Fox Favell, M.D., Sheffield	1845–46.
John Green Crosse, M.D., F.R.S., F.R.C.S.	1846–47.
James Heygate, M.D., F.R.S., Derby	1847–48.
George Norman, Esq., F.R.C.S., Bath	1848–49.
Sir Charles Hastings, M.D., F.G.S., Worcester	1849–50.

OFFICERS OF THE DISTRICT BRANCHES.

BATH AND BRISTOL BRANCH, 1850–51.

PRESIDENT:

EDWARD HODGES, ESQ., M.D., *Bath.*

SECRETARY FOR BRISTOL:

JOHN COLTHURST, ESQ., *The Mall, Clifton.*

SECRETARY FOR BATH:

JOHN S. BARTRUM, *Gay Street, Bath.*

DORSETSHIRE BRANCH, 1850–51.

PRESIDENT:

DR. COWDELL, *Dorchester.*

SECRETARY:

E. OKE SPOONER, ESQ., *Blandford.*

CAMBRIDGE AND HUNTINGDON BRANCH, 1850–51.

PRESIDENT:

DR. WARD, *of Huntingdon.*

SECRETARY:

G. M. MURRAY, ESQ., *Cambridge.*

YORKSHIRE BRANCH, 1850–51.

PRESIDENT:

WILLIAM HEY, ESQ., *Leeds.*

PRESIDENT-ELECT:

CALEB WILLIAMS, ESQ., *York.*

SECRETARY AND TREASURER:

W. D. HUSBAND, ESQ., *York.*

EASTERN BRANCH, 1850–51.

(This Branch includes all Members residing in the Counties of Cambridge, Essex, Huntingdon, Lincoln, Norfolk, and Suffolk.

LOCAL SECRETARIES:

C. R. BREE, ESQ., *Stowmarket*, for the Suffolk Branch.
P. MARTIN DUNCAN, M.B., *Colchester*, for the Essex Branch.
G. M. HUMPHRY, ESQ., *Cambridge*, for Huntingdonshire and the Eastern Division of Cambridge.
J. BALLARD PITT, ESQ., *Norwich*, for Norwich and Norfolk.

NORTH WALES BRANCH, 1850–51.

PRESIDENT:

GEORGE CUMMING, M.D., *Denbigh.*

PRESIDENT-ELECT:

R. LLOYD WILLIAMS, M.D., *Denbigh.*

DISTRICT SECRETARIES:

EDWARD WILLIAMS, M.D., *Wrexham.*
D. KENT JONES, ESQ., *Langefni.*

TREASURER:

JOHN LLOYD, ESQ., *Langefni.*

SHROPSHIRE BRANCH, 1850–51.

PRESIDENT:

W. P. BROOKES, ESQ., *Much Wenlock.*

SECRETARY:

THOMAS JONES DRURY, M.D., F.R.M.C.S., *Shrewsbury.*

LANCASHIRE AND CHESHIRE BRANCH, 1850–51.

PRESIDENT:

W. H. DUNCAN, M.D., *Liverpool.*

VICE-PRESIDENTS:

THOMAS RADFORD, M.D., *Manchester.*
JAMES EDWARDS, M.D., *Chester.*

GENERAL SECRETARY:

JOHN HATTON, ESQ., *Manchester.*

SOUTH-WESTERN BRANCH, 1850–51.

PATRON:

JOHN BLACKALL, M.D., *Exeter.*

PRESIDENT:

P. W. SWAIN, ESQ., *Devonport.*

PRESIDENT-ELECT:

RICHARD L. PENNELL, M.D., *Exeter.*

SECRETARY:

WILLIAM DASHWOOD KINGDON, M.D., *Exeter.*

WEST SOMERSET BRANCH, 1850–51.

PRESIDENT:

H. ALFORD, ESQ., F.R.C.S., *Taunton.*

HONORARY SECRETARY AND TREASURER:

FRANCIS HENRY WOODFORDE, M.D., *Taunton.*

SOUTH-EASTERN BRANCH, 1850–51.

PRESIDENT:

GEORGE SAMUEL JENKES, M.D., *Brighton.*

VICE-PRESIDENTS:

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SECRETARY AND TREASURER:

THOMAS MARTIN, ESQ., *Reigate.*

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T. Stewart Traill, M.D., Professor of Medical Jurisprudence in the University of Edinburgh.

HONORARY CORRESPONDING MEMBERS.

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E. C. Hobson, M.D., Naturalist to the Colony of Van Dieman's Land, Hobart Town.

BELGIUM.

N. Nebau, M.D., Physician in Ordinary to the King of the Belgians, First Physician to the Military Hospital at Brussels.

BRAZIL.

Luis Vicente de Simoni, M.D., Secretary of the Imperial Academy of Medicine of Rio Janeiro.

DENMARK.

Adolph Carl Peter Callisen, Doctor of Medicine and Surgery, Librarian to the Royal Chirurgical Academy of Copenhagen.

C. Otto, M.D. Professor of Pharmacology and Forensic Medicine in the University of Copenhagen.

EAST INDIES.

W. B. O'Shaughnessy, M.D., Professor of the Institutes of Medicine in the Medical College, Calcutta.

FRANCE.

M. Andral, M.D., Professor to the Faculty of Medicine, Paris.

François Lallemand, M.D., late Professor of Clinical Surgery in the University of Montpellier.

P. C. A. Louis, M.D., Physician to the Hôpital La Petié, &c., Paris.

Alf. A. L. M. Velpeau, M.D., Surgeon to the Hôpital La Charité, Professor of Clinical Surgery to the Faculty of Medicine, Paris.

GERMANY.

Karl Friederich Heinrich Marx, M.D., Professor of Medicine in the University of Göttingen.

N. A. Mühry, M.D., Hanover.

Frederich Nassé, M.D., Professor of Clinical Medicine in the University of Bonn.

Fr. Wilh. Openheim, M.D., Hamburgh.

Carl Rokitansky, M.D., Professor of Pathological Anatomy in the University of Vienna.

Philip Francis Von Walther, Doctor of Medicine and Surgery, Professor of Surgery in the University of Munich, and Body Physician to the King of Bavaria.

HOLLAND.

J. L. Schroeder Van Der Kolk, M.D., Professor of Anatomy and Physiology in the University of Utrecht.

Willem Vrolik, M.D., Professor of Anatomy in the Athenæum of Amsterdam, Member of the First Class of the Royal Institute of the Netherlands.

ITALY.

Maurizio Bufalini, M.D., Professor of Clinical Medicine at the Hospital Santa Maria, Florence.

Vincenzo Lanza, M.D., Professor of Practical Medicine in the Royal University of Naples.

PORTUGAL.

Antonio Jose de Lima Leitao, M.D., Physician to the Hospital San Lazaro at Lisbon.

RUSSIA.

F. C. Marcus, M.D., Chief Physician to the Galitzin Hospital, Moscow, Councillor of State, Knight of the Order of St. Anne and St. Wolodmir.

Carl Von Seidlitz, M.D., Professor of Clinical Medicine in the Imperial Medico-Chirurgical Academy of St. Petersburgh.

SPAIN.

Mateo Seoane, M.D., Member of the Council of the University of Salamanca, and late Member of the Spanish Cortes.

SWEDEN AND NORWAY.

D. Holst, M.D., Professor of Medicine in the Royal Frederick's University, Christiana.

Anders Adolph Retzius, M.D., Chir. M. Inspector of the Royal Carolinian Institution, and Professor of Anatomy, M.R.C.S., Stockholm.

Magnus Christian Retzius, M.D., Physician to the King of Sweden, Professor of Chemistry in the Royal Military Academy of Stockholm.

SWITZERLAND.

Henry Clermont Lombard, M.D., Joint Physician to the Hospital of Geneva.

UNITED STATES OF AMERICA.

Robley Dunglison, M.D., Professor of Materia Medica, &c., Jefferson College, Philadelphia.

William Gibson, M.D., Professor of Surgery, Pensylvania.

Thomas D. Mütter, M.D., Professor of Surgery, Jefferson College, Philadelphia.

John Ware, M.D., Professor of Medicine, Cambridge University, Boston.

John C. Warren, M.D., Professor of Anatomy and Surgery, Harward University, Boston.

George B. Wood, M.D., Professor of Materia Medica and Pharmacy in the University of Pennsylvania, one of the Physicians of the Pennsylvania Hospital, and President of the College of Physicians, Philadelphia.

LIST OF MEMBERS.

A.

Abel, Joseph, Esq., Surgeon, Mitchel-Dean, Gloucestershire.
Adams, Dennis, Esq., Surgeon, Cambridge.
Adams, John, Esq., Surgeon, Bridge House, Matlock, Derbyshire.
Adamson, J., Esq., Surgeon, Rye, Sussex.
Adcock, John Fleming, Esq., Surgeon, Little Walsingham, Norfolk.
Addison, William, M.D., F.R.S., F.L.S., 78, Wimpole Street, Cavendish Square, London.
Adye, Arthur, Esq., Surgeon, Bradford, Wilts.
Aikenhead, John, Esq., M.D., Surgeon to the Chorlton-upon-Medlock Dispensary, Manchester.
Ainsworth, James, Esq., Consulting Surgeon to the Royal Infirmary, Manchester.
Ainsworth, Ralph Fawsitt, M.D., Physician to the Royal Infirmary, Manchester.
Alford, Henry, Esq., F.R.C.S., Senior Surgeon to the Taunton and Somerset Hospital, Taunton.
Alford, Richard, Esq., Surgeon, Tewkesbury, Gloucestershire.
Allanson, James, Esq., Surgeon, Bishop-Wilton, Pocklington, Yorkshire.
Allardyce, James, M.D., Cheltenham.
Allen, George, Esq., Surgeon, St. George's, Somersetshire.
Allen, James, Esq., Surgeon, Lecturer on Midwifery in the Medical School, York.
Allison, William, Esq., Surgeon, East Retford, Notts.
Alsop, Anthony, Esq., Surgeon, Bolsover, near Chesterfield, Derbyshire.
Amyott, Thomas E., Esq., Surgeon, Diss, Norfolk.
Anderson, Francis Byne, Esq., Surgeon, Hessle, near Hull, Yorkshire.
Anderson, Frank, Esq., Surgeon, Westbury-on-Trym, Bristol.
Anderton, Charles, Esq., Surgeon, Leigh, near Manchester.
Andrew, Henry, Esq., Surgeon, Truro, Cornwall.
Andrews, Edward, Esq., Surgeon, Titchfield, Hants.
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Appleton, John G., Esq., Surgeon, Luton, Bedfordshire.
Archer, Francis, Esq., Surgeon to the Borough Gaol, Liverpool.
Arden, Henry Alban, Esq., Surgeon, Dorchester, Dorset.
Arnison, John Campbell, Esq., Surgeon, Annandale Town, Heydon Bridge, Northumberland.
Arnison, Charles, Esq., Surgeon, Alston, Cumberland.
Arnold, Benjamin North, M.D., Leamington, Warwickshire.
Arnott, Charles David, M.D., Edin., M.R.C.S.E., Gorleston, Suffolk.
Arrowsmith, J. Yerrow, Esq., Surgeon to the Salop Infirmary, Shrewsbury.
Arthur, Samuel Pellew, Esq., Surgeon, St. Day, near Truro, Cornwall.
Ashford, John, Esq., Surgeon, Hinckley, Leicestershire.

Ashton, James, M.D., Physician to the Infirmary, Stockport, Cheshire.
Ashton, Henry, Esq., Surgeon, Walton-le-Dale, Preston, Lancashire.
Atcherley, Rowland, M.D., (late of Bath.)
Atkins, Alfred, Esq., Surgeon, Paignton, Devon.
Atkinson, T. Parkin, Esq., Surgeon, Kilham, near Driffield, Yorkshire.

B.

Bacon, Charles Edward, M.D., Guildford, Surrey.
Badeley, John Carr, M.D. (Cantab.), Fellow of the Royal College of Physicians, London, Chelmsford, Essex.
Badley, J., Esq., Surgeon, Dudley, Worcestershire.
Bailey, Charles, Esq., Surgeon, Chippenham, Wilts.
Bailey, H. W., Esq., Surgeon, Thetford, Norfolk.
Bainbridge, Frederick, Esq., Surgeon, Harrowgate, Yorkshire.
Bainbrigge, William Henry, Esq., F.R.C.S., Surgeon to the Northern Hospital, Liverpool.
Baines, James, Esq., Surgeon, Guernsey.
Baird, A. W., M.D., Physician to the East Suffolk Hospital, Ipswich.
Bakewell, Samuel Glover, M.D. (Edin.), Oulton Retreat, near Stone, Staffordshire.
Ballard, Edward, M.D., East Retford.
Baller, James H., Esq., Penshurst, Tunbridge, Kent.
Bally, William Ford, Esq., Surgeon, Bath.
Banning, Thomas Haines, M.D., Oswestry, Salop.
Barclay, John, M.D., Member of the Royal College of Physicians, London, Physician to the Infirmary and Fever House, Leicester.
Bardsley, James Lomax, M.D., Consulting Physician to the Royal Infirmary, &c., Manchester.
Barham, Charles, M.D., Physician to the Royal Cornwall Infirmary, Truro.
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Barker, W. S., Esq., Surgeon, Barrow, Suffolk.
Barker, John, Esq., Surgeon, Coleshill, Warwickshire.
Barnard, William, Esq., Surgeon, Fareham, Hants.
Barnes, Thomas, M.D., F.R.S.E., Physician to the Dispensary and Fever Hospital, Carlisle.
Barnett, Samuel, Esq., Surgeon, Ombersley, Worcestershire.
Barnes, Samuel, Esq., F.R.C.S., late Surgeon to the Devon and Exeter Hospital, Exeter.
Baron, John, M.D., F.R.S., Cheltenham.
Barrett, John, Esq., F.R.C.S., Surgeon to the Western Dispensary, Bath.
Barrow, Peter, Esq., Surgeon, Manchester.
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Bartlett, A. H., Esq., Surgeon to the Esst Suffolk Hospital, Ipswich.
Bartlett, J. Bickford, Esq., Surgeon, Teignmouth, Devon.
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Barton, Zephaniah, M.D., Market-Rasen, Lincolnshire.
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Bates, C. P. Ramsey, Esq., Surgeon, Ramsey, Huntingdonshire.
Batt, Edwin Augustine, Esq., Surgeon, Witney, Oxfordshire.

Batt, F. C., Esq., Surgeon, Abergavenny, Monmouthshire.
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Beales, John, Esq., Surgeon, Halesworth, Suffolk.
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Beaumont, James, Esq., Surgeon, Wetherby, Yorkshire.
Beck, Henry, Esq., Surgeon, Needham-Market, Suffolk.
Beckingsale, John Edgar, Esq., Surgeon, Newport, Isle of Wight.
Beddome, J. R., M.D., Romsey, Hants.
Bedingfield, J., M.D., Needham-Market, Suffolk.
Beecroft, Samuel, Esq., Surgeon, Hyde, near Stockport, Cheshire.
Beet, John, Esq., Surgeon, Ashford, Kent.
Begley, William Chapman, A.M., M.B. (Trinity College, Dublin), Lunatic Asylum, Hanwell, Middlesex.
Belcombe, H.S., M.D., Senior Physician to the County Hospital, and Physician to the Retreat, York.
Bell, Rev. David, M.D., Harrington, Cumberland.
Bell, John P., M.D., Hull, Yorkshire.
Bell, Robert, M.D., Wyton, near Hull, Yorkshire.
Bell, Charles William, M.D., Physician to the Manchester Royal Infirmary, &c., Manchester.
Bell, Thomas, Esq., Surgeon, Felstead, Essex
Bell, John, Esq., Surgeon, Grimsby, Lincolnshire.
Bennett, William, M.D., Harrowgate, Yorkshire.
Bennett, Henry, Esq., Surgeon, Shaftesbury, Dorset.
Bennett, Edward, M.D., Stockport, Cheshire.
Bennion, Edward David, Esq., Surgeon, Oswestry, Salop.
Bent, James, Esq., Assistant Surgeon to the Eye Hospital, Manchester.
Bernard, Charles Edward, Esq., Surgeon, Bath.
Berry, Charles, Esq., Surgeon, Liphook, Hants.
Berry, Grove, Esq., Surgeon, Harrowgate, Yorkshire.
Berry, Samuel, Esq., Surgeon, Professor of Midwifery, Queen's College, Birmingham, Surgeon-Accoucheur to the Queen's Hospital, and Surgeon to the Magdalen Asylum, Birmingham.
Best, Henry, Esq., Surgeon, Thetford, Norfolk.
Bevan, John, Esq., Surgeon, Aigburth, near Liverpool.
Bickersteth, Robert, Esq., Senior Surgeon to the Infirmary, Liverpool.
Bicknell, E., Esq., Surgeon to the Self-supporting Dispensary, Coventry.
Bignell, John Beavis, M.D., Physician to the Dispensary, Barnstaple.
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Birchenall, John, Esq., Surgeon, Macclesfield, Cheshire.
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Birdsall, William, Esq., Surgeon, Northampton.
Birkitt, John, Esq., Surgeon, Selby, Yorkshire.
Birtwhistle, William, Esq., Surgeon, Skipton, Yorkshire.
Black, Glass, M.D., Torquay, Devon.
Black, James, M.D., Bolton, Lancashire.

Blackall, John, M.D., Physician to the Devon and Exeter Hospital, Exeter.
Blackburn, Thomas, Esq., Surgeon, Liverpool.
Blackmore, Edward, M.D., Bath.
Blackshaw, Joseph, Esq., Surgeon, Stockport, Cheshire.
Blakiston, Peyton, M.D., F.R.S., Fellow of the Royal College of Physicians, St. Leonard's-on-Sea, Sussex.
Bleeck, Alfred, Esq., Surgeon, Bristol.
Bligh, Richard, Esq., Surgeon, Blunham, St. Neots.
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Bloxam, R. W., Esq., Surgeon, Ryde, Isle of Wight.
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Boddington, William, Esq., Surgeon, Kenilworth, Warwickshire.
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Boisragon, Theodore, M.D., Sussex House, Hammersmith, Middlesex.
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Bowman, Charles, Esq., Surgeon to the General Dispensary, Leicester.
Bowman, Jonathan, M.D., Liverpool.
Box, John, Esq., Surgeon, Abingdon, Berks.
Boyd, William, M.D., Clifton, Bristol.
Brabant, Robert Herbert, M.D., Bath.
Brace, William H., Esq., Surgeon, Bath.
Braithwaite, W., Esq., Surgeon to the Eye and Ear Infirmary, and Lecturer on Midwifery in the Leeds School of Medicine, Leeds.
Bramley, Lawrence, Esq., Surgeon, Halifax, Yorkshire.
Branson, Ferguson, M.D., Physician to the Infirmary, Sheffield.
Bree, C. R., Esq., Surgeon, Stowmarket, Suffolk.
Brent, Robert, M.D., Woodbury, Devon.
Bridge, Stephen F., Esq., Surgeon, Wellington, Somerset.
Brighton, John George, Esq., Surgeon, Kinver, Staffordshire.
Britton, S. G., M.D., Newport, near Barnstaple, Consulting Physician to the North Devon Infirmary, Devon.

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Broadbent, Edward Farr, Esq., Surgeon, Lincoln.
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Brooke, John, Esq., Surgeon, Stockport, Cheshire.
Brookes, William, Esq., Surgeon, Upper Holloway, Middlesex.
Brookes, H. P., Esq., Surgeon, Much Wenlock, Salop.
Brooking, Charles, Esq., Surgeon, Bixham, Devon.
Broughton, H. H., Esq., F.L.S., Surgeon, Preston.
Brown, C. F , Esq., Surgeon, Victoria Square, Clifton.
Brown, George Gwynn, Esq., Surgeon, Stourport, Worcestershire.
Browne, Joseph, M.D., Physician to the Sunderland and Bishop-Wearmouth Infirmary, Sunderland.
Brown, Robert, Esq., Surgeon, Preston, Lancashire.
Brown, Thomas, Esq., Surgeon, Castle-Donington, Leicestershire.
Browne, Isaac P., Esq., Surgeon, Oxford Square, London.
Bryan, J. M., Esq., Surgeon, Northampton.
Bryant, Samuel, Esq., Surgeon, Bristol.
Buckell, Francis, Esq., Surgeon, Romsey, Hants.
Bucknill, Samuel, Esq., Surgeon, Rugby, Warwickshire.
Budd, Robert, Esq., Surgeon, Fawley, Hants.
Budd, Samuel, M.D., Exeter.
Budd, William, M.D., Physician to the Infirmary, Bristol, and Lecturer on the Practice of Medicine at the Bristol Medical School, Bristol.
Bull, Henry Graves, M.D., Hereford.
Bull, John Henry, Esq., Surgeon, Lindfield, Sussex.
Bullar, Joseph, M.D., Southampton.
Bullen, G., Esq., Surgeon to the East Suffolk Hospital, Ipswich.
Bullock, Joseph, Esq., Surgeon, Congleton, Cheshire.
Buncombe, John, Esq., Surgeon, Wellington, Somerset.
Bunny, Joseph, M.D., Newbury, Berkshire.
Burman, James, Esq., Surgeon, Wath, near Rotherham, Yorkshire.
Burman, Thomas Southam, Esq., Surgeon to the Infirmary, Stratford-upon-Avon, Warwickshire.
Burne, John, M.D., 28, Brook Street, Bath.
Burnham, Robt., Esq., Surgeon, Holme on Spalding Moor, Market-Weighton, Yorkshire.
Burridge, Reginald, M.D., Senior Physician to the Taunton and Somerset Hospital, Taunton.
Burrough, Richard Farr, Esq., Surgeon, Dartmouth, Devon.
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Thurnam, John, M.D., Medical Superintendent of the Wilts Lunatic Asylum, York.
Thursfield, Richard, Esq., Surgeon to the United Dispensary, Broseley, Salop.
Thursfield, Thomas, Esq., Surgeon to the Dispensary, Kidderminster, Worcestershire.
Thursfield, William, Esq., Surgeon, Bridgnorth, Salop.
Tickell, T. S., Esq., Surgeon, Wadebridge, Cornwall.
Tiley, William, Esq., Surgeon, Heckfield, near Hartford Bridge, Hants.
Tinker, Frederick, Esq., Surgeon, Hyde, near Stockport, Cheshire.
Tinney, William S., Esq., Surgeon, Ottery St. Mary, Devon.
Tippetts, Richard, Esq., Surgeon, Dartford, Kent.
Tomkin, T., Esq., Surgeon, Witham, Essex.
Tomkins, William, M.D., Yeovil, Somerset.
Toogood, J. Baruch, Esq., Surgeon to the Torbay Infirmary and Dispensary, Torquay, Devon.
Toogood, Jonathan, M.D., Torquay, Devon.
Torr, T. Berry, Esq., Surgeon, Barnstaple, Devon.
Torrance, David, Esq., Surgeon, Rugby, Warwickshire.
Townson, Benjamin Windsor, Esq., Surgeon, Liverpool.
Toynbee, Joseph, Esq., F.R.C.S., F.R.S., Senior Surgeon to St. George's and St. James's General Dispensary, 18, Saville Row, London.
Tracey, Harry, Esq., Surgeon, Dartmouth.
Trevor, William, Esq., Surgeon, Dulverton, Somerset.
Trew, R. N., Esq., Surgeon, Chantrey House, Steyning, Sussex.
Trinder, Charles, Esq., Surgeon, Devizes, Wilts.
Trotman, W., M.D., Physician to the Clifton Dispensary, Clifton, Bristol.
Trotter, Charles, Esq., Surgeon, Stockton-on-Tees, Durham.
Trousdale, William Maw, Esq., Surgeon, West Butterwick, Bawtry, Yorkshire.
Trustram, Charles, Esq., Surgeon, Tunbridge Wells, Kent.
Tucker, Frederick H., Esq., Surgeon, Halifax, Yorkshire.
Tunstall, James, M.D., Resident Physician to the Eastern Dispensary, Bath.
Turner, George, M.D., Senior Physician to the Infirmary, Stockport, Cheshire.
Turner, John, Esq., Surgeon, High Wycombe, Bucks.
Turner, Richard, Esq., Surgeon, Tunbridge Wells, Kent.
Turner, Thomas, Esq., Surgeon to the Royal Infirmary, and Lecturer on Anatomy and Physiology, Manchester.
Turnour, Arthur E., M.D., Denbigh.
Turton, George, Esq., Surgeon Accoucheur to the Dispensary, and Lecturer on Materia Medica and Midwifery at the Medical Institution, Sheffield.
Tutin, Septimus, Esq., Surgeon, Ripon, Yorkshire.
Tweedale, John, M.D., Lynn-Regis, Norfolk.
Twining, Edward, Esq., Surgeon, Hull, Yorkshire.
Tyacke, Nicholas, M.D., Physician to the Infirmary, Chichester.

U.

Underwood, John, Esq., Surgeon, Battle, Sussex.

V.

Vallance, Benjamin, Esq., Surgeon, Brighton.
Valentine, John, Esq., Surgeon, Somerton, Somerset.
Varenne, Ezekiel George, Esq., Surgeon, Kelvedon, Essex.
Vaughan, Lewis, Esq., Surgeon, Builth, Breconshire.
Veasey, H., Esq., Surgeon, Woburn, Bedfordshire.
Vicary, George, Esq., Surgeon, Warminster, Wilts.
Vicary, George Thomas, Esq., Surgeon, Warminster, Wilts.
Vickers, Thomas, Esq., Surgeon, Holywell, Flint.
Vidal, Horace, Esq., Surgeon, Ilfracombe, Devon.
Vinall, Charles, M.D., 4, Wellington Square, Chelsea.
Vincent, S. B., Esq., Surgeon, Botsdale, Suffolk.
Vise, Charles, Esq., Surgeon to the Dispensary, Spalding, Lincolnshire.
Vise, E. B., Esq., Surgeon, Holbeach, Lincolnshire.

W.

Wadams, Edmund, Esq., Surgeon, Malvern, Worcestershire.
Waddington, Edward, Esq., Surgeon, Epworth, near Bawtry, Yorkshire.
Wagstaff, Philip Wynter, Esq., Surgeon, Leighton Buzzard, Bedfordshire.
Wake, Robert, M.D., Honorary Physician and Surgeon to the Dispensary, Southwold, Suffolk.
Waldron, Henry, Esq., Surgeon, Theale, near Reading, Berks.
Waldron, George, Esq., Surgeon, Bath.
Wales, Robert, Esq., Surgeon, Wisbeach, Cambridgeshire.
Wales, T. Garneys, Esq., Surgeon, Downham Market, Norfolk.
Walford, T. L., Esq., Surgeon to the Dispensary, Reading, Berks.
Walker, David Grant, Esq., Surgeon, Budleigh Salterton, Devon.
Walker, Edward Dering, M.D., Extra-Licentiate of the Royal College of Physicians, London, Teignmouth, Devon.
Walker, J. B., Esq., Surgeon, Iver, near Uxbridge.
Walker, Thomas, M.D., Peterborough.
Wallace, Edward, Esq., Surgeon, Carshalton, Surrey.
Wallace, James, Esq., Surgeon, Carshalton, Surrey.
Wallace, Robert Q., Esq., Surgeon, Wisbeach.
Wallis, C. C., Esq., Surgeon, Castle Cary, Somerset.
Wallis, Edward, Esq., Surgeon, Lecturer on Anatomy, Hull, Yorkshire.
Wallis, Frederick, Esq., Surgeon, Bexhill, near Battle, Sussex.
Wallis, George, M.D., Senior Physician to the Infirmary, Bristol.
Wallis, William, Esq., Surgeon, Hartfield, Tunbridge Wells, Kent.
Walsh, John Henry, Esq., F.R.C.S., Surgeon to the Eye Infirmary, Worcester.
Walsh, Thomas, Esq., Assistant Surgeon to the Eye Infirmary, Worcester.
Walter, Frederick, Esq., Surgeon, Birmingham.
Waltham, William, Esq., Surgeon, Holyhead, North Wales.
Walton, Henry Christmas, Esq., Surgeon, Liverpool.
Ward, Thomas, Esq., Surgeon, Southampton.
Ward, Thomas Ogier, M.D., 9, Leonard Place, Kensington, London.
Ward, W., Esq., Surgeon, F.R.C.S., Huntingdon.
Ward, Edward, Esq., Surgeon, Stowmarket, Suffolk.
Ward, John, Esq., Surgeon, Bodmin, Cornwall.

Ware, John, Esq., Surgeon, Clifton, Bristol.
Wargrave, J., Esq., Surgeon, Walton, Norfolk.
Washbourne, Thomas, Esq., Surgeon, Corsham, Wilts.
Waters, Allen, Esq., Surgeon, Exmouth, Devon.
Watkins, Robert W., Esq., Surgeon, Towcester, Northamptonshire.
Watmough, I., M.D., Pocklington, Yorkshire.
Watson, George Churchill, M.D., (Edin.,) Liverpool.
Watson, James, M.D., Bath.
Watson, Samuel, Esq., Surgeon, Cottingham, near Hull.
Watson, Thomas Sandon, M.D., Physician to the Bath Hospital, Bath.
Watts, John, M.D., Daventry, Northamptonshire.
Waylen, W., Esq., Surgeon to the Essex and Colchester Hospital, Colchester.
Webb, Charles, K., Esq., Consulting Surgeon to the Devon and Exeter Lunatic Asylum, Exeter.
Webb, Matthew, Esq., Surgeon, Wellington, Salop.
Webber, Alexander E., Esq., Wellington, Somerset.
Webster, George, M.D., President of the British Medical Association, Dulwich, Surrey.
Webster, J. H., M.D., (Cantab.,) Cambridge.
Weddell, W. B., Esq., Surgeon, Otley, near Leeds.
Weekes, George, Esq., Surgeon, Hurst-Pierpont, near Brighton, Sussex.
Welsh, F. F., Esq., Surgeon, Saffron Waldon, Essex.
Welsh, W. H., M.D., Eccles, near Manchester.
Welshman, Edward, Esq., Southam, Warwickshire.
West, John Townsend, Esq., Surgeon, Shepton-Mallet, Somerset.
West, John Wickens, M.D., Poole, Dorset.
West, Robert Uvedale, Esq., Surgeon, Hogsthorp, near Alford, Lincolnshire.
West, Thomas, M.D., Daventry, Northamptonshire.
West, William Corner, Esq., Surgeon to the Dispensary, Malvern, Worcestershire.
Westall, Edward, Esq., Surgeon, Croyden, Surrey.
Weston, Philip King, Esq., Surgeon, Yoxford, Suffolk.
Whatman, James, Esq., Surgeon, Maidstone, Kent.
Whicher, James, Esq., Surgeon, Petersfield, Hants.
Whimper, G., Esq., Surgeon, Tillingham, Essex.
Whitcombe, Edmund Bancks, Esq., Surgeon, Cleobury, Mortimer, Salop.
White, G. M., Esq , Surgeon to the General Hospital, Nottingham.
White, John Todd, Esq., Surgeon, Kempsey, Worcestershire.
Whitehead, James, Esq., Surgeon to the Manchester and Salford Lying-in Hospital, Manchester.
Whitby, George, Esq., Surgeon, Swaffham, Norfolk.
Whitfield, E., Esq., Surgeon, Tolleshunt-D'Arcy, Essex.
Whitfield, Henry, Esq., Surgeon, Ashford, Kent.
Whittaker, Joseph, Esq., Surgeon, Stapleton, Trowbridge.
Whiting, J. B., Esq., Surgeon to the Lynn and West Norfolk Hospital, Lynn-Regis, Norfolk.
Whiting, John, M.D., Member of the Royal College of Physicians, Physician to the West Norfolk and Lynn Hospital, &c., Lynn Regis, Norfolk.
Whitton, Corbett, M.D., Llangollen, Denbighshire.
Whytehead, Henry Yates, M.D., Crayke, near York.

Wickenden, Joseph, Esq., Surgeon, Birmingham.
Wickham, J. M., Esq., Surgeon, Sutton Scotney, Hants.
Wickham, W. J., Esq., Surgeon to the Hospital, Winchester.
Wight, Alexander, Esq., Surgeon, Old Kent Road, Southwark, London.
Wightman, J., Esq., Surgeon, Cawood, Selby, Yorkshire.
Wilding, Richard, Esq., Surgeon, Church Stretton, Salop.
Wilding, R., Esq., Surgeon, Blackburn, Lancashire.
Wilkes, George Frederick, Esq., Surgeon, Ashford, Kent.
Wilkin, Henry, Esq., Surgeon, Walton, Suffolk.
Wilkinson, H., Esq., Surgeon, Rotherham, Yorkshire.
Wilkinson, M. A. Eason, M.D., Physician to the Manchester Royal Infirmary, Manchester.
Wilkinson, William Cradock, Esq., Surgeon to the Dispensary, Spalding, Lincolnshire.
Wilks, Charles, Esq., Surgeon, Charing, Kent.
Williams, D. W., Esq., Surgeon, Menai Bridge, North Wales.
Williams, Henry, Esq., Surgeon, Llanrwst, Denbighshire.
Williams, William, Esq., M.D., Mold, Flint.
Williams, H. L., M.D., Beverley, Yorkshire.
Williams, James, F.R.S., Surgeon to the Dispensary, Southwold, Suffolk.
Williams, Caleb, Surgeon to the Retreat, and Lecturer on Materia Medica in the Medical School, York.
Williams, Charles J. B., M.D., F.R.S., Fellow of the Royal College of Physicians, 7, Holles Street, Cavendish Square, London.
Williams, Edward, Esq., M.D., Wrexham, Denbighshire.
Williams, Henry, Esq., Surgeon, Llansaintfraid, near Conway, Carnarvonshire.
Williams, Hugh, Esq., Surgeon, Thrapston, Northamptonshire.
Williams, John Calthrop, M.D., (Edin.) Fellow of the Royal College of Physicians of Edinburgh, Physician to the General Hospital, near Nottingham, and Visiting Physician to the General Lunatic Asylum, Nottingham.
Williams, John, M.D., Beverley, Yorkshire.
Williams, John, Esq., Surgeon, Bewdley, Worcestershire.
Williams, John, Esq., Surgeon, Dursley, Gloucestershire.
Williams, Peter, Esq., Senior and Consulting Surgeon to the Flintshire General Dispensary, Holywell.
Williams, Philip Henry, M.D., Physician to the Dispensary, Worcester.
Williams, Richard Lloyd, M.D., F.R.C.S., Consulting Surgeon to the Denbighshire Infirmary, Visiting Physician to the North Wales Hospital for the Insane, Denbigh.
Williams, William, Esq., Surgeon, Guilsborough, near Northampton.
Williams, William Rumsey, Esq., Surgeon, Carnarvon.
Williamson, Henry Merrell, Esq., House Surgeon, Chorlton-upon-Medlock Dispensary, Manchester.
Wills, George Frederick, Esq., Surgeon, Crewkerne, Somerset.
Wilson, F. H., Esq., Surgeon, Rye, Sussex.
Wilson, Henry, Esq., Surgeon, Runcorn, Cheshire.
Wilson, John Grant, Esq., Surgeon, Bristol.
Wilson, Thomas, Esq., Surgeon, Nottingham.
Wilson, William Murray, Esq., Surgeon, Horsforth, near Leeds.
Wilson, W. J., Esq., Surgeon to the Royal Infirmary, Manchester.

Wilton, J. W., Esq., Surgeon to the Infirmary, Gloucester.
Windsor, John, Esq., F.L.S., Surgeon to the Eye Hospital, Manchester.
Winslow, Forbes, M.D., Sussex House, Hammersmith.
Wing, H., Esq., Surgeon, Bury St. Edmund's, Suffolk.
Winn, William, Esq., L.R. & S., Glasgow, L.S.A., Manchester.
Winter, T. B., Esq., Surgeon, Brighton, Sussex.
Wisemann, W. W., Esq., Surgeon, Ossett, near Wakefield, Yorkshire.
Wolstenholme, George, Esq., Surgeon, Bolton, Lancashire.
Wood, Abraham, Esq., F.R.C.S., Rochdale, Lancashire.
Wood, Charles Walker, Esq., Surgeon, Woodhouse Eaves, near Loughborough, Leicestershire.
Wood, Hugh, Esq., Surgeon, Sheffield, Yorkshire.
Wood, Miles Astman, Esq., Surgeon to the Dispensary, Ledbury, Herefordshire.
Wood, Peter, M.D., Physician to the Royal Infirmary, Dispensary, Fever Wards, and Lunatic Asylum, Manchester.
Wood, Robert, Esq., Surgeon, Ashton-under-Lyne, Lancashire.
Woodforde, Francis Henry, M.D., (Edin.) M.R.C.S., Physician to the Taunton and Somerset Hospital, Taunton.
Woodhouse, Richard, M.D., Reading, Berks.
Woodman, James, M.D., Chichester.
Woods, Charles John, Esq., Surgeon, Godmanchester, Huntingdonshire.
Workman, Thomas, Esq., Surgeon, Guernsey.
Workman, Thomas Keate, Esq., Surgeon, Reading, Berks.
Worship, J. Lucas, Esq., Surgeon, Riverhead, Sevenoaks, Kent.
Worthington, W., Esq., Senior Surgeon to the Infirmary, Lowestoft, Suffolk.
Wraith, Hope Samuel, Esq., Surgeon, Over Darwin, Lancashire.
Wright, Edward W., M.D., Shipston-on-Stour, Worcestershire.
Wright, Francis, M.D., Market Harborough, Leicestershire.
Wright, Henry, Esq., Surgeon, March, Cambridgeshire.
Wright, John, Esq., F.R.C.S., Surgeon to the General Infirmary, Derby.
Wyman, George, Esq., Surgeon, Alcester, Warwickshire.
Wyman, W. S., Esq., Surgeon, Kettering, Northamptonshire.

Y.

Yate, Frederick, Esq., Surgeon, Godalming, Surrey.
Yonge, James, M.D., Fellow of the Royal College of Physicians, Plymouth, Devon.
Young, Edward William, Esq., Surgeon, Henley-upon-Thames, Oxfordshire.
Young, F. A., Esq., Surgeon, Hawkehurst, Kent.
Young, James, Esq., Surgeon, Wells, Norfolk.

NAMES OF MEMBERS RECEIVED TOO LATE TO BE INSERTED IN THEIR PROPER PLACES.

Bennett, Samuel Butler, M.D., M.R.C.S., Senior Physician to the Ardwick and Ancoats Dispensary, Manchester.

Cross, John, Esq., Surgeon, Much Molton, near Liverpool.

Growse, Robert, jun., Esq., Surgeon, Tunbridge.

As it is scarcely possible to avoid errors in printing so numerous a list of Members, the Secretary is anxious, wherever they are committed, that they may be amended; and will therefore feel obliged if those Members whose designation and address are not rightly inserted, or whose Christian names are omitted, will send the requisite corrections.

THE FOLLOWING ARE

THE PRINCIPAL OBJECTS

TO WHICH THE ATTENTION OF THE

PROVINCIAL MEDICAL AND SURGICAL ASSOCIATION

IS DIRECTED.

1st.—Collection of useful information, whether speculative or practical, through Original Essays, or Reports of Provincial Hospitals, Infirmaries, or Dispensaries, or of private practice.

2nd.—Increase of knowledge of the Medical Topography of England, through statistical, meteorological, geological, and botanical inquiries.

3rd.—Investigations of the modifications of Endemic and Epidemic Diseases, in different situations, and at various periods, so as to trace, so far as the present imperfect state of the art will permit, their connections with peculiarities of soil or climate, or with the localities, habits, and occupations of the people.

4th.—Advancement of Medico-Legal Science, through succinct reports of whatever cases may occur in Provincial Courts of Judicature.

5th.—Maintenance of the honour and respectability of the Profession, generally, in the Provinces, by promoting friendly intercourse and free communication of its Members, and by establishing among them the harmony and good feeling which ought ever to characterize a liberal profession.

THE LAWS

OF THE

PROVINCIAL MEDICAL AND SURGICAL ASSOCIATION.

1st.—That a Provincial Medical and Surgical Association be formed.

2nd.—That the Association be managed by a President, a President of the Council, Secretary or Secretaries, and Council.

3rd.—That the President be appointed annually, by a General Meeting of Members convened for that purpose, at whichever of the principal towns may be appointed; the place of such Meeting being prospectively notified each year.

4th.—That at this Meeting shall be presented a Report, prepared by the Secretary or Secretaries, of the general state of the Association, its proceedings, and pecuniary accounts; the Report to be afterwards printed, and a copy supplied to every Member.

5th.—That at this Meeting one of the Members shall be appointed to give, at the next Annual Meeting, an account of the state or progress of Medical Science during the last year; or an Oration on some subject connected with Medical Science; or a Biographical Memoir of some eminent cultivator of Medical Science, who may have resided in the Provinces.

PRESIDENT OF THE ASSOCIATION.

6th.—That the office of President be honorary, and conferred on some senior Physician or Surgeon of eminence, resident in any of the provincial towns comprised in the circle of the Association.

OFFICERS AND COUNCIL.

7th.—That the Secretary or Secretaries be resident in Worcester, the place of publication, the duties being to attend to the printing of the *Transactions*, and to correct the press; to be present at the

meetings of the Council, and to keep the minutes thereof; to correspond with the Members of the Association; and to receive and submit to the Council all papers transmitted for publication.

8th.—That the Council consist of a President and —— Members, to be selected from the principal provincial towns. The Council, with whom must rest the chief responsibility of publication, to have full power of deciding on all papers transmitted; and the consent of three of its Members must be obtained before any paper can be published. It shall also be the duty of the Council to receive the subscriptions, when due, in their respective districts.

9th.—That the President of the Council be also the Treasurer of the Association, and keep the financial accounts.

REGULATIONS OF THE DISTRICT BRANCHES.

10th.—That Members of the Association be at liberty to form District Branches wherever it may suit their convenience.

11th.—That in order to facilitate the formation of such Branches, and maintain uniformity amongst them, the General Council provide suitable instructions for the guidance of those who may unite in instituting them.

12th.—That conformity with these instructions be further ensured by the initiating proceedings and organization of each Branch being submitted to the General Council for their revision and approval.

13th.—That the District Branches be free to govern themselves as their respective Members may think fit; but that the by-laws ordaining the special government be submitted to the General Council previously to their taking effect, in order to guard against the possibility of any such by-laws contravening the fundamental laws of the Association.

14th.—That the District Branches be empowered to present for Election such of their Members as it may be deemed advantageous to the general and local interests of the Association to place on the General Council.

15th.—That the expenses incurred by the District Secretaries in conducting the proceedings of the District Branches be defrayed

from the general fund, provided such expenses do not, in any instance, exceed one-seventh part of the guinea subscribed by each Member enrolled in the District Branch.

16th.—That if any circumstance arise in the formation of District Branches which calls for a larger expenditure than what is allowed by the foregoing resolution, such expenses, provided they do not exceed one-fourth of the guinea, may be allowed by a statement of the circumstances being made known to the General Council.

ELECTION OF MEMBERS, ANNUAL MEETINGS, &c.

17th.—That each Member, on applying for admission, be nominated by two Members, as a pledge of eligibility.

18th.—That at each Annual Meeting the place of meeting for the ensuing year shall be announced.

19th.—That any Member wishing to propose a new law, or an alteration in an existing law, must send notice of his intention to the Secretary or Secretaries three months previous to the Anniversary Meeting, which will be circulated with the Report of the Council.

20th.—That the Association appoint Honorary Members at the Anniversary Meetings only.

21st.—That the Association appoint Members in foreign countries, to be styled "Honorary Corresponding Members," from whom communications, respecting the state of medicine in those countries, are expected to be received.

22nd.—That if a Member be accused of professional impropriety, or misconduct, and a majority of those present upon the Annual or a Special General Meeting consider the charge to be proved, the name of such Member shall be removed from the list; but no measure of this kind shall be adopted without the accused having two months' notice of the charge to be brought against him, and of the parties by whom he has been accused, that he may, if he so please, explain or defend his conduct.

BENEVOLENT FUND.

23rd.—That a Medical Benevolent Society, under the restrictions proposed in the Report of the Committee presented to the Anniversary Meeting at Oxford, be connected with the Association.

PAYMENT OF SUBSCRIPTIONS, &c.

24th.—Each Member of the Association to pay one guinea admission, and the same amount annually afterwards; the subscription to commence from the 1st of January each year, and to be considered as due, unless notice of its being withdrawn be given to the Secretary or Secretaries antecedently to the year for which it would be payable; for such subscription each Member shall receive a copy of each and all publications issued for the general use of the Members of the Association. But if any Member's subscription remain unpaid twelve months after it shall have become due, the *Medical Journal*, and other publications of the Society, shall be withheld from such Member till his arrears be paid; and when any Member has been in arrears of subscription for the space of three years, application shall be made for the same by the General Secretary, and if the arrears be not paid in *three months*, the name of that Member shall be omitted from the list of Subscribers; but this omission shall not be deemed, either in honour or equity, as releasing any Gentleman from his subscriptions owing during his Membership.

25th.—That those Members who have not an opportunity of paying their subscriptions to a Member of the Council resident in their district, are requested to pay it through the medium of their own bankers, to Messrs. Robarts and Co., London, for Messrs. Berwick and Co., Worcester, to the credit of the Association, or by a Post-office order, sent to the President of the Council or the Secretary, which mode of remittance is specially pointed out, from being found the most convenient in conducting the business of the Society.

26th.—That all Papers and other communications connected with the routine business of the Association be addressed to the Secretary, at Worcester, and forwarded carriage free.

27th.—That Messrs. Berwick and Co., Old Bank, Worcester, be the Bankers of the Association.

JAMES P. SHEPPARD,

SECRETARY.

RULES OF THE BENEVOLENT FUND

OF THE

PROVINCIAL MEDICAL AND SURGICAL ASSOCIATION.

Before specifying the Rules which are to direct the proceedings of this department of the Association, it is proper to repeat, in this place, the main principles on which it is established. It is not intended either to be a Benefit Society, or an Assurance Club; but, strictly speaking, a benevolent or charitable institution, founded and promoted for the express purpose of assisting our professional brethren, when struggling under the pressure of disease or other calamities. It is likewise proposed, under circumstances of peculiar urgency and distress, to administer relief to the widow or family of a professional man, who may have been deprived of the support and protection of a husband or parent. While, therefore, the sole design of this Society is to hold out the hand of charity and benevolence to a suffering and afflicted brother, or his family, it will not countenance improvidence or idleness, or evil habits of any kind.

The principle above stated has received the sanction of three successive meetings of the "Provincial Medical and Surgical Association;" and the following resolutions were finally adopted at the Anniversary held at Manchester, on the 20th and 21st of July, 1836:—

1st. That a charitable fund be created by donations and subscriptions of members of the Association, to be called "The Benevolent Fund of the Provincial Medical and Surgical Association."

2nd. That contributions be received from all persons friendly to the objects of the Society, though belonging neither to the Association nor to the profession.

3rd. That the object of the fund be the relief of medical men* under severe and urgent distress, occasioned by sickness, accident, or any other calamity.

4th. That any medical man labouring under such afflictions be considered a fit object for the charity.

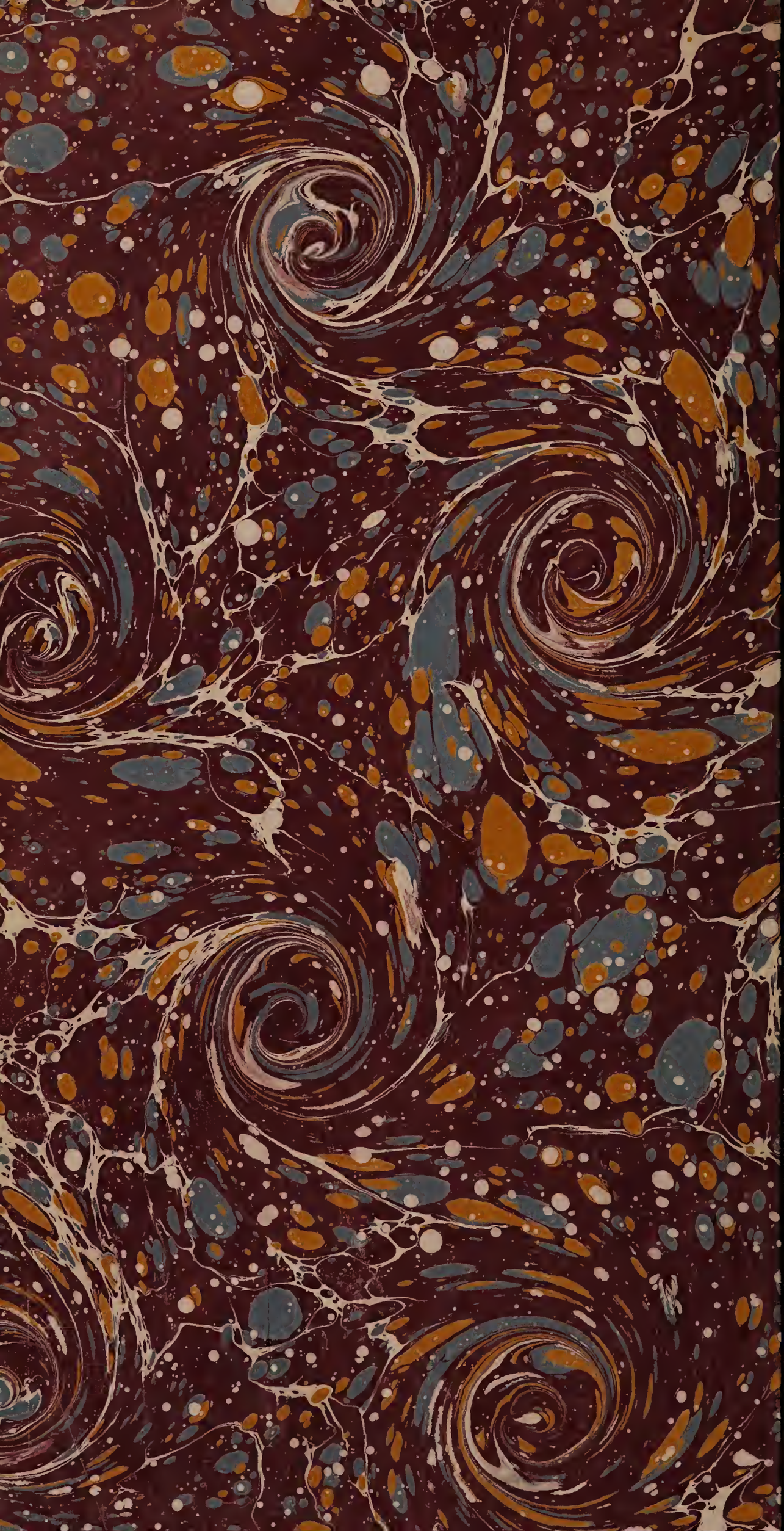
5th. That the claims of contributors shall, as far as possible, have the preference; but that contributions to the fund give no claim of right to relief, the fund being one of pure charity, and that each case be judged according to the urgency of the distress.

6th. That under circumstances of peculiar emergency, relief may be extended to the widows and orphans of medical men, it being understood that it is not the design of this fund to relieve medical men from the necessity of providing for their families by ordinary life insurances, and such other means as prudence dictates.

7th. That the management of the fund be conducted by Committees of the contributing members, annually appointed; the Central Committee to be in London, and Local Committees, subordinate to the Central, in each of the principal cities and towns—the Central Committee having power to appoint Local Committees wherever they may be required.

The following Gentlemen were appointed Members of the Committee of the Benevolent Fund, at the Hull Anniversary Meeting:—

SIR JAMES CLARK, BART.,
DR. G. BURROWS,
DR. CANNON,
JOHN CHURCHILL, ESQ.,
DR. W. CONOLLY,
DR. J. CONOLLY,
T. C. COOK, ESQ.,
THOS. COPELAND, ESQ.,
DR. FORBES,
THOMAS HUDLETT, ESQ.,
THOMAS HUNT, ESQ.,
JOHN INCE, ESQ.,
DR. LEAR,
FREDERICK SALMON, ESQ.,
JOHN SODEN, ESQ.,
JOSEPH TOYNBEE, ESQ.,
DR. CHARLES WEST,
DR. CHARLES J. B. WILLIAMS.

All communications to the Central Committee to be addressed to the Treasurer and Secretary, William Newnham, Esq., Farnham, Surrey.

* The Society will not acknowledge any one as a fit object of relief who has not received a regular professional education, and is not either a Doctor of Physic, or a Member of the College of Surgeons, or of the Apothecaries' Company.